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SOIL FUNGI IN RELATION TO DISEASES OF THE IRISH POTATO IN SOUTHERN IDAHO

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INTRODUCTION

In a former paper it was shown that planting disease-free seed potatoes (*Solanum tuberosum*) on lands never before in cultivation could not be considered a guarantee of a disease-free product (*10*).[1] Research studies with the powdery-dryrot organism (*Fusarium trichothecioides* Wollenw.) (*9*) and with *Fusarium radicicola* Wollenw., the cause of a blackrot (*11*) of the Irish potato tuber, indicated that these organisms might be well distributed in the desert soils. From the results of the 1915 plantings it was assumed that the infection which was observed in the harvested crop must have proceeded from organisms already present in the virgin desert soil, but since no attempts had been made to isolate any of the organisms concerned, this assumption remained unverified.

In an attempt to verify previous conclusions, plantings of disease-free seed were again made in 1916 on lands never before planted to potatoes, and isolations of fungi were made from the soils. It is the purpose of this paper to set forth the results obtained from the plantings of 1916 and to report the fungi obtained from these isolations.

1916 PLANTINGS

In the spring of 1916 eight plots (No. 1–8) were planted with disease-free seed potatoes on irrigated land previously cropped with grain and alfalfa or clover, or with grain alone, but never with potatoes; one (No. 9) on irrigated virgin desert land never before in any crop; one (No. 10) on dry-farming land previously in grain but never in potatoes; and four (No. 11–14) on dry-farming land reclaimed from the desert in the spring of 1916 for the special purpose of planting these plots. Two of these plots (No. 7–8) were planted on the grounds of the experiment

[1] Reference is made by number (italic) to "Literature cited," p. 98–99.

station at Jerome, Idaho, on irrigated land never before planted with potatoes, but previously cropped with grain and alfalfa. These two plots consisted of a few hundred hills each. The remaining plots were planted in cooperation with farmers in southern Idaho, as follows: Plots 1 and 2 on irrigated, previously cultivated land near Blackfoot, Idaho; plot 3 on irrigated, previously cultivated land at Aberdeen, Idaho, on the grounds of the Aberdeen Experiment Station; plot 4 on irrigated alfalfa land, near Twin Falls, Idaho; plot 5 on irrigated alfalfa land near Murtaugh, Idaho; plot 6 on irrigated clover land near Jerome, Idaho; plot 9 on irrigated, virgin desert land, near Jerome, Idaho; plot 10 on dry-farming land previously cultivated but never irrigated, on the grounds of the Aberdeen Experiment Station, Aberdeen, Idaho; and plots 11 to 14 on virgin desert land not subject to irrigation, near Aberdeen, Idaho. Plots 1, 4, 5, 6, and 9 consisted of about 1 acre each; plot 2 of about 0.5 acre; plots 3 and 10 of about 0.2 acre each; and plots 11 to 14 of about 0.1 acre each.

The varieties planted in the test plots were as follows: Idaho Rural, Netted Gem, Carmen 3, Early Six Weeks, Irish Cobbler, People's, and Pearl. The seed tubers were selected in such a manner that no seed piece showing any internal or external evidence of disease was used. Every tuber was carefully examined in cutting, and the slightest discoloration was sufficient cause for discarding it. No dryrot-infected tubers were used, and all slight bruises were cut out to insure the freedom of the seed piece from any germs of disease which might be lurking in the bruised tissues. No tubers showing any evidence of common scab or the sclerotia of *Rhizoctonia solani* were employed. In addition to these precautionary measures, the seed tubers for plots 3, 7, 8, 10, 11, 12, 13, and 14, and the Netted Gem of plot 6, were selected from 1915 plantings from hills which showed no evidence of disease. The seed for the other plantings was selected from commercial stock.

All seed tubers used for the plots were disinfected after cutting for at least two hours in solutions of mercuric chlorid, strength 1:1,000, or stronger. Wherever planting machinery was employed, all parts of the machine were thoroughly scrubbed in a solution of mercuric chlorid (1:500). The seed for one plot at the Jerome Station (plot 7) was given special treatment as follows: The seed tubers were selected from disease-free hills in 1915. At planting time these tubers were taken to the laboratory and thoroughly scrubbed with a solution of mercuric chlorid (1:1,000) after which they were cut into seed pieces, only pieces showing clean white tissue being used. The seed pieces were then disinfected for two hours in a solution of mercuric chlorid (1:500) and carried to the field in the disinfecting solution, from which they were picked out by hand. They were then dropped into the row prepared to receive them and were immediately covered. It was believed that in this manner all

chance of contamination between the disinfecting bath and the field could be entirely removed.

During the growing season, inspections of each plot were made from time to time; but frequent frosts prevented an accurate determination of foliage and other diseases of the plants. Disease determinations were therefore reserved until harvest time. Those presented in this paper are confined to such diseases as were observed on the tubers when dug. At harvest time disease conditions were determined by digging 100 or more hills in different parts of each plot and examining the tubers from each hill separately. Disease percentages are expressed in terms of the percentage of hills infected with each disease and in the percentage of tubers infected. Vascular infection due principally to *Fusarium* spp. was the most abundant. Tuber-rots were occasionally found. Common scab and the sclerotia of *Rhizoctonia solani* were found on a small percentage of the tubers in most plots. The disease conditions observed in the several plots are given in Table I.

TABLE 1.—*Description of potato plots and percentages of disease observed at harvest*

Plot No.	Land reclaimed.	Previous cropping.	Character of farming.	Variety of potatoes.	Percentage of hills infected.				Percentage of diseased tubers (by weight).
					Vascular infection.	Tuber-rot.	Common scab.	Rhizoctonia.	
1	1909	1910–11, grain; 1912–1914, alfalfa: 1915, wheat.	Irrigation	People's	20	1	2	1	26.6
2	1908	1908–9, grain: 1910–11, fallow: 1912–1915, grain.	do	do	14	0	1	12	16.2
3	1909	1910–11, grain; 1912–1915, alfalfa.	do	Netted Gem	25	1	0	1	10.1
				Idaho Rural	13	0	3	0	8.2
4	1907	1907, oats; 1908–1915, alfalfa.	do	Idaho Rural	13	1	3	0	6.0
				Netted Gem	4	1	0	1	1.1
5	1908	1908, wheat; 1909–1915, alfalfa.	do	Netted Gem	12	0	0	0	10.7
				Carmen 3	21	0	3	0	12.3
				Six Weeks	13	0	0	0	8.9
6	1910	1911–12, grain; 1913–1915, clover.	do	Irish Cobbler	6	0	1	0	4.3
				Netted Gem	15	0	0	0	10.7
7	1910	1910, barley; 1911–1915, alfalfa.	do	People's	16	4	1	0	19.0
				Idaho Rural	7	0	3	0	9.0
				Idaho Rural	5	1	15	0	20.0
8	1910	See plot 7	do	Netted Gem	10	0	0	0	7.0
				People's	3	1	1	1	.....
				Six Weeks	20	2	14	0	22.4
9	1916	Virgin desert land	do	Netted Gem	22	2	0	2	11.4
				People's	38	8	0	2	29.3
10	1912	1913, fallow; 1914, barley; 1915, fallow.	Dry farming.	Idaho Rural	34	0	6.7	0	48.0
				Netted Gem	37	2.5	0	0	39.0
				Idaho Rural	20	0	0	0	8.0
11	1916	Virgin desert land	do	Netted Gem	15	0	0	0	7.0
				Pearl	10	0	1	0	4.0
12	1916	do	do	See plot 11	(a)	(a)	(a)	(a)	(a)
13	1916	do	do	do	(a)	(a)	(a)	(a)	(a)
14	1916	do	do	do	(a)	(a)	(a)	(a)	(a)

[a] No percentages determined.

In plots 12 to 14 no accurate estimate of the percentage of diseased plants or tubers could be arrived at. No rains fell on the plots after planting time and no previous cultivation to conserve the moisture had been given the land. The plants remained very small throughout the

season and very few produced any tubers. These three plots would not be mentioned in this report were it not for the fact that two tubers infected with common scab were found in plot 12 and that tubers showing infection of the vascular tissue were found in all three plots. The mycelium of *Rhizoctonia solani* was found on plant stems in each of the plots but the sclerotia were not found on any of the tubers. Isolations made in the laboratory from the discolored vascular tissue of tubers from each of these three plots showed the presence of several species of fungi, including *Fusarium radicicola*. A record of these plantings is therefore included because of the additional proof afforded of the presence in desert soils of parasitic fungi. Similar conditions also existed in plot 11, but better care was given this plot during the growing season and a better crop was obtained, rendering it possible to secure more accurate and extensive data.

When the plots were dug, infected tubers were collected from each and taken to the laboratory, where isolations were made. Isolations from discolored vascular tissues gave a variety of results: some remained sterile, some gave fungi which could not be associated in any way with the disease in question, a few gave pure cultures of *Fusarium radicicola*, and others gave this fungus associated with other fungi and bacteria. *F. radicicola* was isolated from the vascular tissue of tubers from each of the plots. Isolations from rotted tubers gave similar results, *F. radicicola* being the organism most frequently isolated. No attempt has been made to determine the organism associated with the common scab observed on the product from these plots. The scab is, however, similar in appearance to the common scab (*Actinomyces chromogenus* Gasperini) of the East, and it is assumed that it is caused by the same or a similar organism.

The average percentage of disease found present in the plots was as follows:

On irrigated, previously cultivated land (plots 1 to 8), percentage of hills infected: Vascular infection, 12.7 per cent; tuber-rot, 0.7 per cent; common scab, 2.7 per cent; Rhizoctonia or russet scab, 1 per cent; percentage of tubers diseased, all diseases, by weight, 12.03 per cent.

For the two varieties of plot 9, on irrigated, virgin desert land, percentage of hills infected: Vascular infection, 30 per cent; tuber-rot, 5 per cent; common scab, 0 per cent; Rhizoctonia or russet scab, 2 per cent; percentage of tubers infected, all diseases, by weight, 20.3 per cent.

For the two varieties of plot 10, on dry-farming land, previously cultivated, percentage of hills infected: Vascular infection, 35.5 per cent; tuber-rot, 1.25 per cent; common scab, 3.3 per cent; Rhizoctonia or russet scab, 0 per cent; percentage of tubers infected, all diseases, by weight, 43.5 per cent.

For the three varieties of plot 11, on dry-farming land, virgin desert soil, percentage of hills infected: Vascular infection, 15 per cent; tuber-

rot, 0 per cent; common scab, 0.33 per cent; Rhizoctonia or russet scab, 0 per cent; percentage of tubers infected, all diseases, by weight, 6.33 per cent.

In 1915 the averages for similar plots (10) were as follows:

Plots on irrigated, previously cultivated land: Vascular infection, 26 per cent; tuber-rot, about 0.5 per cent; common scab, 4.7 per cent; and Rhizoctonia or russet scab, about 2.8 per cent.

On virgin desert land, irrigated: Vascular infection, 29.3 per cent; tuber-rot, 5.6 per cent; common scab, 9.3 per cent; and Rhizoctonia or russet scab, 11.3 per cent.

No plots were planted on dry-farming land in 1915. In detail, the percentages of disease observed in the 1915 plantings are shown in Table II.

TABLE II.—*Percentages of diseases of potatoes observed in the plantings in 1915*

Plot No.	Reclaimed.	Previous cropping.	Variety of potato.	Percentage of hills infected.			
				Common scab.	Rhizoctonia.	Tuber-rot.	Vascular infection.
		AT JEROME STATION.					
1	1910	1910, barley; 1911–1914, alfalfa.	Idaho Rural	0	0	3.00	36
			do	1.00	0	0	40
			Netted Gem	0	0	0	10
			Rural New Yorker	2.00	0	2.00	21
			Pearl	0	0	1.00	14
			People's	0	0	0	15
			Red Peachblow	0	0	0	20
			Burbank	0	0	0	5
		Average		0.37	0	0.77	20
		IN COOPERATION WITH IDAHO FARMERS.					
2	1907	1907, wheat; 1908–1914, alfalfa.	Carmen 3	30	8	0	46
3	1907	do	Netted Gem	0	0	0	37
4	1908	1908–1915, orchard land, cropped with alfalfa and beans.	do	0	6	0	44
5	1907	1907, grain; 1908–1914, alfalfa.	do	0	1	1	2
6	1908	1908, grain; 1909–1913, idle; 1914, grain.	do	0	0	0	5
7	?	Alfalfa, long period of years.	Red Peachblow	2	5	0	20
8	?	do	Netted Gem	0	1	0	20
9	?	do	Idaho Rural	10	4	0	41
10	1915	Raw desert land	do	38	44	6	32
11	1915	do	Netted Gem	0	5	10	53
12	1915	do	do	2	12	1	19
13	1915	do	Idaho Rural	1	1	1	10
14	1915	do	do	10	7	5	29
15	1915	do	People's	5	1	11	33

It will be seen that the percentages were much lower in 1916 than in 1915, and in this connection it is interesting to note that the prevailing temperature for the season of 1916 was much lower than for 1915. The temperature during the summer of 1915 was extremely high, while that of the season of 1916 was unusually low. It will be observed that, as in 1915, the percentage of infection was lower in the plots planted on irrigated, previously cultivated land than in the plots planted on virgin desert land.

ISOLATION OF FUNGI FROM THE SOIL

During the 1916 season 109 cultures were made from the soil, either in the field directly from the soil itself or in the laboratory from soil samples collected in the field. In making the soil cultures, whether in the field or in the laboratory, only sterile instruments, containers, and media were employed, and every possible precaution was taken to guard against air and other contaminations. It is believed that all such dangers were reduced to a minimum. In all, 58 soil cultures were made in the laboratory from five soil samples, and 51 in the field directly from the soil. Hereinafter the designation "soil sample" will be used in referring to the several sources of the cultures made in the laboratory from soil samples, and the words "soil group" in referring to the cultures made in the field directly from the soil. The soils employed are described as follows:

SOIL SAMPLE 1.—From a rather heavy clay loam on the grounds of the Jerome Experiment Station, at Jerome, Idaho. The land was reclaimed in 1910, planted to barley, and seeded with alfalfa, remaining in alfalfa until the spring of 1916, when it was plowed and put in condition for planting potatoes. The sample was taken on June 7, prior to the planting of the potatoes.

SOIL SAMPLE 2.—From the same source as soil sample 1, and taken a few feet distant. Sample taken on June 7.

SOIL SAMPLE 3.—From a desert soil from which the desert plants have just been removed and the soil put in condition for potato planting. Located just south of the city of Jerome, Idaho. The soil was a sandy-clay loam, reclaimed in May, 1916. The sample was taken on June 20 from a portion of the field which had not been planted. Plot 9, of the 1916 experimental plot, planted with disease-free seed potatoes, was planted in this field.

SOIL SAMPLE 4.—From a desert soil, supporting a typical growth of sagebrush and desert grasses, located about 25 miles northwest of Aberdeen, Idaho. The land had never been in cultivation and was situated nearly 20 miles from the nearest agricultural lands. Sample taken on August 18.

SOIL SAMPLE 5.—From the same type of soil as soil sample 4, located about 2 miles from the place where soil sample 4 was taken. Sample taken on August 18.

SOIL GROUP A.—From a very sandy soil in the Snake River Canyon, 15 miles southeast of Jerome, Idaho, and about 250 feet above the level of the river. This was a desert soil supporting only a very scant growth of desert grasses and dwarfed sagebrush plants. Cultures made on June 21.

SOIL GROUP B.—From a desert soil located about 11 miles southeast of Jerome, Idaho. The soil was principally of clay with a slight admixture of sand and was supporting a heavy growth of sagebrush and desert grasses. Cultures made on June 21.

SOIL GROUP C.—From the same soil as samples 1 and 2, on the grounds of the Jerome Experiment Station. The cultures were made on June 23, from soil in a portion of the field which had not been planted to potatoes.

SOIL GROUP D.—From the same soil as sample 4. Cultures made on August 18.

In taking the soil samples and in making the soil cultures, the writer was assisted by Mr. George L. Zundel,[1] each worker being present at the taking of each soil sample and in making each original soil culture. Mr. Zundel also gave valuable assistance in the examination and identification of the fungi obtained from the cultures, each worker verifying the observations of the other so far as possible.

On account of the necessity of closing the work early in the season, very little attention was given to the cultures made from samples 4 and 5, or to the cultures of soil groups B and D. For the same reason, a number of fungus forms which appeared in the remaining cultures were neglected, and undoubtedly many fungi were lost in transfer. The fungi reported in this paper therefore do not represent nearly the number of forms which appeared, but merely those which there was time to properly isolate and identify. In Table III is given a list of the fungi isolated and identified, showing the number of times each fungus form was isolated from each soil sample or group of soil cultures.

TABLE III.—*List of fungi isolated from the soil*

Name of fungus.	Number of times isolated.	Number of times isolated from each soil sample or group of soil cultures.								
		Group.				Sample.				
		A	B	C	D	1	2	3	4	5
Aspergillus sp.	1							1		
Absidia spinosa Lender	1					1				
Absidia glauca Hagem	2			1			1			
Absidia sp	2					1		1		
Chaetomella sp.	2		1				1			
Fusarium affine Faut and Lamb	1						1			
Fusarium dimerum Penz	1					1				
Fusarium lanceolatum, n. sp.	2					1	1			
Fusarium acuminatum Ell. and Ev., emend. Wollenw.	6			2		1	2	1		
Fusarium sanguineum Sherb	2							2		
Fusarium elegantum, n. sp	3	1					1	1		
Fusarium idahoanum, n. sp	2	1								1
Fusarium trichothecioides Wollenw	2							2		
Fusarium culmorum var. *leteius* Sherb	4	2		1		1				
Fusarium discolor var. *triseptatum* Sherb	4					2		2		
Fusarium subpallidum Sherb	2	2								
Fusarium aridum, n. sp	1		1							
Fusarium nigrum, n. sp	1	1								
Fusarium radicicola Wollenw	9	1		1		1	2	4		
Macrosporium commune Rabenh	2					1	1			
Monascus sp	1	1								
Mucor sphaerosporus Hagem	2							2		
Mucor janssseni Lender	3							3		

[1] Then Scientific Assistant, United States Departtment of Agriculture; now Assistant Professor of Biology, Brigham Young College, Logan, Utah.

TABLE III.—*List of fungi isolated from the soil*—Continued

Name of fungus.	Number of times isolated.	Number of times isolated from each soil sample or group of soil cultures.								
		Group.				Sample.				
		A	B	C	D	1	2	3	4	5
Mucor spinescens Lender	1							1		
Mucor circinelloides Van Tieghem	1							1		
Mucor botryoides Lender	1							1		
Mucor plumbeus Benorden	1						1			
Mucor sp. (undifferentiated)	9	1		5			2		1	
Penicillium strains, as arranged by Dr. Charles Thom and Miss M. B. Church:										
Penicillum viridicatum Westling (.363)	1			1						
(.712) Approximately *P. viridacatum* Westling	1		1							
(.452.3) A green Penicillium, suggestion of *P. pulitans* Westling	1						1			
(.447) A strain of *P. expansum* Link	1						1			
(.480) Penicillium, blue-green series	1						1			
(.621) A blue-green Penicillium, fragrant	1	1								
(.500) Penicillium, coremiform series	1						1			
(.504) Penicillium, coremiform series	1							1		
(.508) Penicillium, coremiform series	1							1		
(.515) Penicillium, coremiform series	1							1		
The 4 preceding forms, not far from *P. expansum* Link.										
(.629) (.630) Penicillium, soil series (Cf. *P. humicula* Oudemans) tending toward coremiform production?	2	2								
(.401) Penicillum, soil series	1					1				
(.447) Penicillium, soil series	1						1			
(.451.1) Penicillium, soil series	1						1			
(.452.2) Penicillium, soil series	1						1			
(.597) Penicillium, soil series	1								1	
(.598) Penicillium, soil series	1								1	
(.604) Penicillium, soil series	1								1	
(.675) Penicillium, soil series	1	1								
(.756) Penicillium, soil series	1			1						
(.601) Penicillium, soil series, two strains mixed	1								1	
(.606) Penicillium, mixture, but chiefly soil series, admixture is coremiform	1								1	
Periconia byssoides Pers	4	1	2					1		
Rhizopus nigricans Ehr	1			1						
Rhizoctonia solani Kühn	5	2				1		2		
Stemphylium piriforme Bos	3	3								
Stemphylium paxianum V. Szabo	2	1	1							
Trichoderma sp	4			2		1	1			
Thamnidium elegans Link	2						1	1		
Torula sp	4		1			1	1	1		
Verticillium sp. (771)	1			1						
Verticillium sp. (419)	2					2				
Verticillium sp. (825)	3	1		1		1				
Verticillium sp. (603)	1									1
Verticillium sp. (477)	2					1		1		
Sterile mycelium, brown	1									1
Sterile mycelium, white	20	5		1	1	8	4	1		
Sterile mycelium, pink	3	2					1			
Sterile mycelium, yellow	1									1
Sterile mycelium, buff-colored, producing brownish sclerotia-like bodies	1	1								

DETAILED CONSIDERATION OF THE FUNGI ISOLATED

ASPERGILLUS

One strain of Aspergillus was isolated once from sample 3. This was identified by Dr. Thom and Miss Church (see p. 93).

ABSIDIA

Three species of the genus Absidia were identified as follows: *A. glauca* Hagem, isolated once from sample 2 and once from group C; *A. spinosa* Lender, isolated once from sample 1; and one unidentified species, isolated once each from samples 1 and 3. These were identified by Mr. Zundel

CHAETOMELLA

One species of the genus Chaetomella was twice identified, once each from group B and sample 2. This species is briefly described as follows: Mycelium white to gray or darker; perithecia separate, scattered on the mycelium but without distinct subicle, ovate-globose, 50 to 125 μ in diameter, black, beset with straight or curved bristle-like black hairs, 100 to 250 μ long, about 7 μ in diameter, septate, the septa distinguishable with difficulty; spores elliptical, olivaceous, 8 to 15 by 4 to 8 μ; character of sporophore uncertain.

FUSARIUM

Fourteen species of the genus Fusarium were isolated and identified. Because of the economic importance of this genus very careful attention was given each form isolated and in their identification, except where otherwise indicated in the following pages, authentic cultures were available for comparison. The writer is indebted to Mr. L. L. Harter, of this Office, for cultures of *Fusarium dimerum* Penz., *F. subpallidum* Sherb., *F. acuminatum* Ell. and Ev., emend Wollenw. *F. discolor* var. *triseptatum* Sherb., and *F. sanguineum* Sherb., as well as for many other cultures used in the comparisons, and to Dr. H. A. Edson, of this Office, for cultures of several strains of Fusarium which, it was thought, might be identical with certain of those isolated. Five of the strains isolated apparently differed from all species heretofore described and are herein presented as new species. The species isolated are as follows:

SECTION DIMERUM [1]

Fusarium affine Faut and Lamb (*4, p. 68; 13, v. 14, p. 1125; 14, p. 126*).

The organism isolated agreed very closely with the original description given by Fautrey and Lambotte (*4*) and appeared to be very similar, both in microscopic characters and in habit of growth, to the strain

[1] The arrangement and grouping is after the plan suggested by Wollenweber (*20*).

studied by Sherbakoff (*14, p. 126*) though no authentic culture was available for comparison.

Habitat: In tubers and stems of *Solanum tuberosum* and in greenhouse soil, New York (*14, p. 126*). Isolated once from Idaho soils from sample 2.

Fusarium dimerum Penz (*1, p. 37, fig. 2–3; 8, p. 484; 12, p. 566; 13, v. 4, p. 704; 14, p. 127; 22, drawings 85–91*).

The organism isolated differed slightly from the original description by Penzig (*8, p. 484*), but the differences were not considered important enough to justify the establishment of a new species. On comparing it with a strain isolated from potatoes by Sherbakoff (*14, p. 127*), it was found to be identical, except that the conidia were slightly broader and longer and the growth on most media somewhat more rapid. In comparison with drawings of *F. dimerum* made by Wollenweber (*22*), the conidia appeared to be identical with those of several European strains of the organism. The organism isolated is briefly described as follows: Conidia lunar, slightly pedicillate, typically 1-septate, often 0-septate, sometimes 2-septate, very rarely 3-septate (only one 3-septate conidium was observed), borne singly on the mycelium, forming, on most media, a more or less continuous slimy layer, from slightly hyalin to light cinnamon buff,[1] on string-bean agar and steamed-potato media, a tufted growth from white to pink and cinnamon buff. The conidial measurements are as follows:

0-septate, 10 to 17 by 2.5 to 3.8 μ.

1-septate, 11 to 20 by 2.5 to 4.5 μ.

2-septate, 12 to 20 by 3 to 4.6 μ.

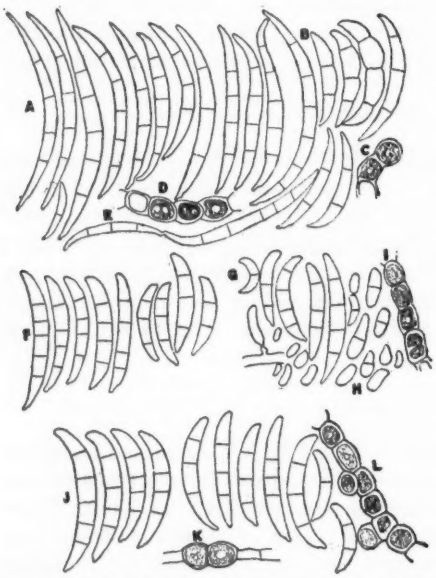

FIG. 1.—*A–E, Fusarium lanceolatum* n. sp. × 500: *A*, typical conidal forms sporodochia and pseudopionnotes; *B*, short conidia, some with swollen, barrel-like cells common on media containing an abundance of moisture; *C, D*, Chlamydospore in chains; *E*, Germinating conidium. *F–I, Fusarium elegantum*, n. sp. ×500: *F*, typical conidia from sporodochia; *G, H*, conidia from aerial mycelium; *G*, macroconidia; *H*, microconidia; *I*, chlamydospores in chains. *J–L, Fusarium nigum*, n. sp. ×500: *J*, typical conidia from sporodochia and aerial mycelium; *K, L*, chlamydospores in chains and groups.

[1] Colors given in this paper are according to RIDGWAY, Robert. COLOR STANDARDS AND COLOR NOMENCLATURE. 43 p., 53 col. pl. Washington, D. C., 1912.

The average proportion of 1-septate conidia observed was 93 per cent; of 2-septate, 6 per cent; of 0-septate, 1 per cent (in mature cultures, 15 to 30 days old).

Habitat: On tubers and stems of *Solanum tuberosum* in Germany (*1*), and in Minnesota (*14*), on fruits of *Citrus medica* in Italy (*8*). Isolated once from Idaho soils from sample 1.

SECTION GIBBOSUM

Fusarium lanceolatum, n. sp. (Pl. A, 7, 8; fig. 1, A–E).

Conidia typically in pseudopionnotes, but also in aerial mycelium and sporodochia from nearly straight to strongly curved, usually distinctly pedicillate, typically 3-, 4-, and 5-septate, 6- and 7-septate common, higher septations rare, the 3-septate averaging 34 by 3.5 (22 to 52 by 2.5 to 5) μ, the 4-septate, 40 by 3.8 (22 to 60 by 2.8 to 5) μ, and the 5-septate, 48 by 4.1 (36 to 70 by 2.8 to 5.7) μ; aerial mycelium scantily developed, white when present, to dark maroon when well filled with conidia; sporodochia and pseudopionnotes ochraceous-orange at first, becoming dark maroon, often brighter shades of red to Brazil red; substratum on steamed potato often a bright orange, yellow modification on rice becoming brown with age; chlamydospores singly and in chains.

Habitat: Isolated twice from Idaho soils, once each from samples 1 and 2. When inoculated into potato tubers, no decay resulted.

The conidial measurements on various media are as follows:

FROM PSEUDOPIONNOTES ON STEAMED-POTATO PLUG, CULTURE 43 DAYS OLD

1-septate rare, 20 by 3 μ, only a few measured.
3-septate 23 per cent, 37 by 3.6 (28 to 50 by 3 to 4.3) μ.
4-septate 30 per cent, 48 by 4.2 (34 to 57 by 3 to 5) μ.
5-septate 44 per cent, 53 by 4.4 (43 to 68 by 3 to 5.7) μ.
6-septate 3 per cent, 62 by 4.8 (50 to 72 by 4.3 to 5) μ.
7-septate rare, 65 by 4.5 μ.

FROM PSEUDOPIONNOTES ON STEAMED MELILOTUS STEM, CULTURE 56 DAYS OLD

1-septate 2 per cent, 19 by 3 (14 to 27 by 2.4 to 3.5) μ.
2-septate 2 per cent, 20 by 3 (14 to 33 by 2.4 to 3.6) μ.
3-septate 20 per cent, 32 by 3 (26 to 48 by 2.5 to 3.8) μ.
4-septate 22 per cent, 38 by 3.3 (28 to 60 by 2.8 to 4.8) μ.
5-septate 42 per cent, 48 by 4 (38 to 64 by 3 to 5) μ.
6-septate 10 per cent, 58 by 4 (44 to 70 by 3 to 5) μ.
7-septate 2 per cent, 64 by 4.2 (56 to 72 by 3.5 to 5) μ.

FROM PSEUDOPIONNOTES ON POTATO AGAR (10 PER CENT GLUCOSE), CULTURE 60 DAYS OLD

1-septate 0.4 per cent, 18 by 3 (14 to 24 by 2.5 to 3.5) μ.
2-septate 1.5 per cent, 19 by 3 (15 to 26 by 2.5 to 3.8) μ.
3-septate 20.0 per cent, 33 by 3.4 (22 to 52 by 2.8 to 4) μ.
4-septate 20.5 per cent, 37 by 3.5 (28 to 60 by 3 to 4) μ.
5-septate 57 per cent, 47 by 3.5 (38 to 70 by 2.8 to 4) μ.
6-septate 0.2 per cent, 56 by 3.5 (42 to 72 by 3 to 4.2) μ.
7-septate 0.4 per cent, 60 by 3.6 (42 to 76 by 3 to 4.2) μ.

FROM AERIAL MYCELIUM ON STRING-BEAN AGAR, CULTURE 65 DAYS OLD

1-septate rare.
2-septate 2 per cent, 22 by 3 (20 to 36 by 2.5 to 3.2) μ.
3-septate 30 per cent, 36 by 4 (22 to 44 by 3 to 5) μ.
4-septate 11 per cent, 37 by 4.2 (22 to 48 by 3 to 5) μ.
5-septate 55 per cent, 44 by 4.5 (40 to 64 by 3 to 5.3) μ.
6-septate 1 per cent, 52 by 4.5 (42 to 68 by 3 to 5.4) μ.
7-septate 1 per cent, 56 by 4.5 (42 to 70 by 3 to 5.3) μ.
8- and 9-septate rare.

SUMMARY AND AVERAGE OF THE PRECEDING MEASUREMENTS

1 septate up to 2 per cent, 19 by 3 (14 to 27 by 2.4 to 3.5) μ.
2-septate up to 2 per cent, 20 by 3 (14 to 36 by 2.4 to 3.8) μ.
3-septate up to 30 per cent, 34 by 3.5 (22 to 52 by 2.5 to 5) μ.
4-septate up to 30 per cent, 40 by 3.8 (22 to 60 by 2.8 to 5) μ.
5-septate up to 57 per cent, 48 by 4.1 (36 to 70 by 2.8 to 5.7) μ.
6-septate up to 10 per cent, 61 by 4.2 (42 to 72 by 3 to 5.4) μ.
Higher septations rare.

SECTION ROSEUM

Fusarium acuminatum Ell. and Ev., emend. Wollenw. (*3, p. 441; 13, v, 14, p. 1125–1126; 14, p. 142; 21, p. 269–270, pl. 16, fig. G; 22, drawings 166, 168, 170*).

The strain isolated agreed very closely with a culture of the organism furnished by Dr. L. L. Harter. Conidial measurements and habits of growth on various media were very similar.

Habitat:

On partly decayed plants, especially on stems, roots, and tubers, also on fruits' Found on Solanum, Ipomoea, Fagus (beechnuts), and *Impatiens balsamina* in the United States of America (*21, p. 269*).

Isolated six times from Idaho soils, twice from group C, once from sample 1, twice from sample 2, and once from sample 3. This organism was once isolated from old roots of alfalfa which had been cut back in harvesting.

SECTION FERRUGINOSUM

Fusarium sanguineum Sherb. (*14, p. 193–196; pl. 3, fig. 7–8; pl. 6, fig. 1; 22, drawing 165*).

Identified by comparison with a strain of the organism isolated from potatoes by Sherbakoff (culture furnished by Dr. L. L. Harter).

Habitat:

On rotted tubers of *Solanum tuberosum* in association with *F. lutulatum* var. *zonatum*, Ithaca, N. Y. (*14, p. 194*).

Isolated twice from Idaho soils, from sample 3.

SECTION ELEGANS

Fusarium elegantum, n. sp. (Pl. A, 5, 6; fig. 1, F–I).

Microconidia usually present in aerial mycelium elliptical to oval, or slightly curved, typically 0-septate, often 1-septate, the 0-septate averaging 7.5 by 2.8 (4.5 to 11 by 2 to 4.5) μ, the 1-septate averaging

12 by 3.2 (10 to 17 by 2.8 to 4.5) μ; macroconidia in aerial mycelium, pseudopionnotes, and sporodochia, slightly curved, typically broader at the middle and in the upper half of their length, somewhat abruptly constricted toward the apex, slightly pedicillate, typically 3- and 4-septate, the 3-septate averaging 29 by 4.2 (19 to 41 by 3.5 to 5.5) μ, the 4-septate averaging 33 by 4.6 (26 to 46 by 3.6 to 5.7) μ, sometimes 2-septate, 1- and 5-septate rare; aerial mycelium typically well developed, white; sporodochia and pseudopionnotes, light salmon-orange to salmon-orange on most media, salmon-orange to old rose on Irish potato agar with 10 per cent of glucose; substratum but slightly discolored or not at all, slight-yellow modification on steamed rice; flesh colored to pinkish wartlike plectenchymic bodies often abundant, especially on steamed melilotus stems; sclerotia often present, dark blue (on steamed potato media); chlamydospores usually present in old cultures, but never abundant, intercalary in the mycelium.

Habitat: Isolated three times from Idaho soils as follows: Once each from samples 2 and 3 and once from group A. Attempts to induce decay in Irish potato tubers by inoculating with this organism were unsuccessful.

The conidial measurements on various media are as follows:

CONIDIA FROM SPORODOCHIA ON STEAMED MELILOTUS STEM, 19 DAYS OLD

0-septate 1 per cent (immature, about same as 3- and 4-septate).
2-septate 5 per cent, 18 by 4.3 (15 to 22 by 4 to 5) μ.
3-septate 50 per cent, 31 by 4.7 (23 to 36 by 3.5 to 5.5) μ.
4-septate 41 per cent, 35 by 5.2 (28 to 39 by 4.3 to 5.7) μ.
5-septate 3 per cent, 36 by 5.7 (28 to 40 by 4.2 to 5.7) μ.

CONIDIA FROM AERIAL MYCELIUM ON STEAMED MELILOTUS STEM, 21 DAYS OLD

Microconidia:
0-septate 14 per cent, 8 by 2.2 (7 to 11 by 2 to 2.8) μ.
1-septate 11 per cent, 13 by 3 (10 to 14 by 2.8 to 3.6) μ.
Macroconidia:
2-septate 3 per cent, 19 by 3.5 (18 to 21 by 2.8 to 3.6) μ.
3-septate 68 per cent, 28 by 4.2 (21 to 32 by 3.6 to 4.5) μ.
4-septate 4 per cent, 32 by 4.5 (28 to 36 by 4.3 to 5) μ.
5-septate rare (only one observed) 35 by 5 μ.

CONIDIA FROM SPORODOCHIA ON STEAMED POTATO-TUBER PLUG, 49 DAYS OLD

2-septate 1 per cent, 19 by 4.2 (16 to 22 by 4.3 to 5) μ.
3-septate 51 per cent, 30 by 4.3 (21 to 35 by 3.8 to 5) μ.
4-septate 48 per cent, 33 by 4.5 (26 to 41 by 4 to 5) μ.
5-septate rare (only one observed) 34 by 5.1 μ.

CONIDIA FROM PSEUDOPIONNOTES ON STEAMED POTATO-TUBER PLUG, 20 DAYS OLD

0-septate 1 per cent, immature.
1-septate rare, 20 by 4 (19 to 26 by 3.5 to 4.5) μ.
2-septate 1 per cent, 22 by 4.5 (20 to 26 by 3.8 to 5.0) μ.
3-septate 68 per cent, 30 by 4.3 (21 to 36 by 3.6 to 5) μ.
4-septate 30 per cent, 33 by 4.6 (29 to 41 by 3.6 to 5.7) μ.

CONIDIA FROM SPORODOCHIA ON STRING-BEAN AGAR, CULTURE 25 DAYS OLD

3-septate 77 per cent, 34 by 4 (26 to 41 by 3.8 to 4.8) μ.
4-septate 23 per cent, 34 by 4.2 (30 to 46 by 3.8 to 5) μ.
5-septate rare, only two observed, averaging 41 by 4.5 μ.

CONIDIA FROM AERIAL MYCELIUM ON POTATO AGAR, WITH 10 PER CENT OF GLUCOSE ADDED, CULTURE 26 DAYS OLD

Microconidia:
0-septate 84 per cent, 7 by 3.5 (4.5 to 11 by 2.5 to 4.5) μ.
1-septate 7 per cent, 11 by 3.5 (10 to 17 by 3 to 4.5) μ.
Macroconidia:
2-septate 1 per cent, 23 by 3.8 (19 to 26 by 3.4 to 4.5) μ.
3-septate 8 per cent, 26 by 4 (19 to 29 by 3.8 to 5) μ.
4-septate rare.

The conidia are rarely normal on this medium. Conidia from sporodochia and pseudopionnotes are usually swollen, with barrel-shaped cells. The sporodochia, often converging into a pseudopionnotal layer, soon become overgrown with mycelium containing a very high percentage of microspores.

SUMMARY AND AVERAGE OF THE FOREGOING MEASUREMENTS

Microconidia:
0-septate up to 84 per cent, 7.5 by 2.8 (4.5 to 11 by 2 to 4.5) μ.
1-septate up to 11 per cent, 12 by 3.2 (10 to 17 by 2.8 to 4.5) μ.
Macroconidia:
0-septate considered immature.
1-septate rare, 20 by 4 (19 to 26 by 3.5 to 4.5) μ.
2-septate up to 5 per cent, 20 by 4 (15 to 26 by 3.4 to 5) μ.
3-septate up to 68 per cent, 29 by 4.2 (19 to 41 by 3.5 to 5.5) μ.
4-septate up to 48 per cent, 33.4 by 4.6 (26 to 46 by 3.6 to 5.7) μ.
5-septate rare, 35 by 5 (28 to 41 by 4.2 to 5.7) μ.

It will be seen from the description that this organism lacks one of the typical characters of the section Elegans—namely, the characteristic vinaceous hues. This color reaction appears with this organism only on media rich in glucose but other characters are such that the writer feels justified in placing it in this section.

Fusarium idahoanum, n. sp. (Pl. B, 4–6; fig. 2, M–P.)

Microconidia always present in aerial mycelium and often in sporodochia and pseudopionnotes elliptical to oval, sometimes slightly curved, 0-septate, averaging 7 by 2.4 (4 to 12 by 1.5 to 3.5) μ; macroconidia slightly curved, typically gradually attenuated toward the apex, slightly pedicillate, typically 3-septate, averaging 25 by 4.1 (18 to 40 by 3 to 5) μ, 1-, 2-, and 4-septate common, 5-septate rare; aerial mycelium typically well developed, white at first, becoming pink to mallow-purple, often orange-pink when well filled with conidia, frequently developing shades of yellow on Irish potato agar with 10 per cent glucose; sporodochia and pseudopionnotes, light orange to orange; substratum (steamed rice) yellow to shades of brown, sometimes, in places, shades of pink to vina-

ceous, on Irish potato agar with 10 per cent of glucose, a rich amber-brown.

Habitat: Isolated twice from Idaho soils, once each from sample 5 and group A. When inoculated into Irish potato tubers, a very slight decay resulted. The organism was recovered from the decayed tissue; however, the decay was so slight that it is probable that the organism has no great parasitic faculty.

The measurements for the conidia on various media are as follows:

CONIDIA FROM SPORODOCHIA ON STEAMED POTATO PLUG, CULTURE 47 DAYS OLD

Microconidia:
- 0-septate rare, 6 by 1.8 μ, only a few measured.

Macroconidia:
- 1-septate 7 per cent, 16 by 3 (11 to 19 by 2 to 3.4) μ.
- 2-septate 19 per cent, 18 by 3.3 (12 to 19 by 2.6 to 3.4) μ.
- 3-septate 72 per cent, 24 by 4 (18 to 34 by 3 to 4) 9μ.
- 4-septate 2 per cent, 30 by 4.4 (26 to 34 by 3.8 to 5.3) μ.
- 5-septate rare, 29 by 4 μ.

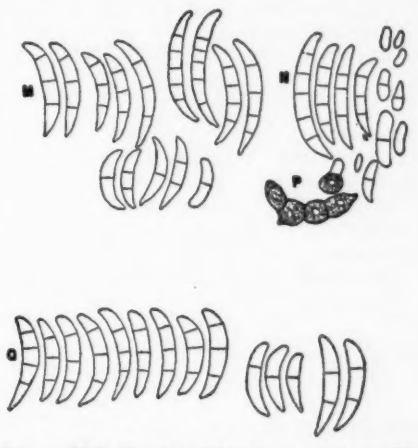

FIG. 2.—*M-P*, *Fusarium idahoanum*, n. sp. × 500: *M*, conidia from sporodochia; *N*, *O*, conidia from aerial mycelium; *N*, macroconidia: *O*; microconidia, 0- and 1-septate; *P*, chlamydospores formed in conidia. *Q*, *Fusarium aridum*, n. sp.: Typical conidial forms from sporodochia and aerial mycelium. × 500.

CONIDIA FROM AERIAL MYCELIUM ON IRISH POTATO AGAR, WITH 10 PER CENT OF GLUCOSE, CULTURE 48 DAYS OLD

Microconidia:
- 0-septate 21 per cent, 7 by 2.5 (4 to 11 by 1.5 to 3.4) μ.

Macroconidia:
- 1-septate 9 per cent, 14 by 3.3 (11 to 17 by 2.2 to 3.7) μ.
- 2-septate 7 per cent, 16 by 3.3 (13 to 19 by 2.5 to 3.8) μ.
- 3-septate 56 per cent, 26 by 4 (19 to 38 by 3.5 to 4.9) μ.
- 4-septate 6 per cent, 30 by 4.3 (24 to 39 by 3.8 to 5.1) μ.
- 5-septate 1 per cent, 34 by 4.3 (30 to 39 by 3.8 to 5) μ.

CONIDIA FROM PSEUDOPIONNOTES ON STEAMED MELILOTUS STEM, CULTURE 57 DAYS OLD

Microconidia:
- 0-septate 16 per cent, 6 by 2.2 (5 to 11 by 1.8 to 3.5) μ.

Macroconidia:
- 1-septate 7 per cent, 14 by 3.2 (9 to 16 by 2.4 to 3.6) μ.
- 2-septate 6 per cent, 17 by 3.4 (12 to 21 by 2.6 to 3.8) μ.
- 3-septate 64 per cent, 28 by 4 (18 to 40 by 3.5 to 5) μ.
- 4-septate 7 per cent, 30 by 4.2 (22 to 40 by 3.5 to 5) μ.
- 5-septate rare.

CONIDIA FROM AERIAL MYCELIUM ON STRING-BEAN AGAR, CULTURE 61 DAYS OLD

Microconidia:
0-septate 12 per cent, 8 by 2.5 (6 to 12 by 1.5 to 3) μ.
Macroconidia:
1-septate 15 per cent, 13 by 3 (10 to 18 by 2.8 to 3.6) μ.
2-septate 8 per cent, 18 by 3.3 (14 to 21 by 3 to 4) μ.
3-septate 61 per cent, 24 by 4.4 (19 to 37 by 3.5 to 5) μ.
4-septate 3 per cent, 29 by 4.5 (19 to 42 by 3.5 to 5.2) μ.
5-septate 1 per cent, 30 by 4.6 (26 to 43 by 4 to 5.2) μ.

SUMMARY AND AVERAGE OF THE FOREGOING MEASUREMENTS

Microconidia:
0-septate up to 21 per cent, 7 by 2.4 (4 to 12 by 1.5 to 3.5) μ.
Macroconidia:
1-septate up to 15 per cent, 14.7 by 3.1 (9 to 19 by 2 to 3.7) μ.
2-septate up to 19 per cent, 17 by 3.3 (12 to 21 by 2.5 to 4) μ.
3-septate up to 72 per cent, 25.5 by 4.1 (18 to 40 by 3 to 5) μ.
4-septate up to 7 per cent, 29.7 by 4.4 (19 to 42 by 3.5 to 5.2) μ.
5-septate up to 1 per cent, 32 by 4.4 (26 to 43 by 3.8 to 5.2) μ.

SECTION DISCOLOR

(*2, 5, 6, 9, 18, 19, p. 206; 22, drawing 305*).

Fusarium trichothecioides Wollenw.

The organism isolated agreed in every particular with the original description given by Wollenweber (*5*). On comparing it with a strain of *F. trichothecioides* used by the writer in previous experiments it was found to be identical. The organism isolated from the soil was inoculated into potato tubers and a typical powdery-dryrot produced.

Habitat: First reported in 1912 by Jamieson and Wollenweber (*5*) on potato tubers from Western States and demonstrated to be the cause of a dryrot of western potatoes and capable of attacking growing plants. In 1913 a species of Fusarium, called "*Fusarium tuberivorum* Wilcox and Link," was reported as causing a dryrot of potatoes in Nebraska by Wilcox, Link, and Pool (*18*). This fungus was demonstrated by Wollenweber (*19, p. 206*) and by Carpenter (*2*) to be identical with *F. trichothecioides* Wollenw., which opinion was later concurred in by one of the authors of *F. tuberivorum* (*6*), who demonstrated it to be a cause of potato-wilt. Investigations on the part of the writer failed to prove it a wilt-producing organism under ordinary field conditions in Idaho, but demonstrated it to be a prevalent cause of storage-dryrot in that State (*9*). Isolated twice from Idaho soils from sample 3.

Fusarium culmorum var. **leteius** Sherb. (*14, p. 242–244, pl. 4, fig. 1, 2, 10; pl. 5, fig. 9, text fig. 1D$_2$, 43*):

No authentic culture of the original strain of this organism was available for comparison, but the conidial dimensions and growth characters were so similar to those of the original description given by Sherbakoff

(*14, p. 242–244*) that there was no doubt in the mind of the writer as to its identity.

Habitat: On rotted tubers of *Solanum tuberosum* in New York (*14, p. 242*). Isolated four times from Idaho soils as follows: Twice from group A and once each from group C and sample 1.

Fusarium discolor var. **triseptatum** Sherb. (*14, p. 239–240, pl. 4, fig. 5–6; pl. 5, fig. 10; text fig. 1W$_1$, 42; 22, drawings 319, 320*).

The strain isolated differed from an authentic culture of the species (furnished by Dr. L. L. Harter) by having slightly smaller conidia. Otherwise the organism isolated appeared to be identical with that originally described by Sherbakoff (*14, p. 239–240*). In his Fusaria Autographice Delineata, Wollenweber (*22*) considers *F. discolor* var. *triseptatum* a synonym of *F. discolor* Ap. and Wollenw., which in turn he makes a synonym of *F. sambucinum* Fuch.

Habitat: On rotted tubers of *Solanum tuberosum*, together with *F. coeruleum*, Long Island, N. Y. (*14, p. 239*). Isolated four times from Idaho soils, twice each from samples 1 and 3

Fusarium subpallidum Sherb. (*14, p. 230–234; pl. 5, fig. 12, text fig. 39; 22, drawing 326*).

The form isolated was identified by comparing with a culture of the original strain (culture furnished by Dr. L. L. Harter), with which it was found to be identical in every important particular.

Habitat: On superficial dryrot of potato tubers from Louisiana (*14*). Isolated twice from Idaho soils from group A.

Fusarium aridum, n. sp. (Pl. B, 1-3; fig. 2, Q).

Conidia in aerial mycelium, pseudopionnotes, and sporodochia, slightly curved, typically broader in the upper half of their length, usually suddenly constricted at the apex, slightly pedicillate, typically 3-septate, averaging 27 by 4.2 (18 to 36 by 3 to 5) μ; 1, 2, and 4-septate usually present, the 4-septate rare; aerial mycelium typically well developed, white at first, becoming pink to vinaceous; substratum on steamed-potato plug, often vinaceous to Vandyke red; on Irish potato agar with 10 per cent of glucose vinaceous-purple to carmen; steamed rice shades of yellow and brown; sporodochia and pseudopionnotes, salmon-orange to light-orange. Chlamydospores not observed.

Habitat: Isolated once from Idaho soils, from group B. When inoculated into potato tubers, a slight decay resulted, which bore a close resemblance to the type of decay produced by *F. trichothecioides*. The decay proceeded downward into the tuber from the point of inoculation for about ⅛ inch during the first 10 days, but though kept at temperatures varying from 5° to 35° C. for several weeks, failed to proceed farther. The writer therefore does not consider it capable alone of causing extensive rotting of potato tubers.

Conidial measurements on various media are as follows:

FROM AERIAL MYCELIUM ON STEAMED MELILOTUS STEM, CULTURE 23 DAYS OLD

1-septate 1 per cent, 19 by 3.5 (17 to 23 by 3.4 to 3.8) μ.
2-septate 2 per cent, 19 by 3.8 (17 to 25 by 3.4 to 4) μ.
3-septate 97 per cent, 27 by 4 (22 to 34 by 3.5 to 4.2) μ.

FROM AERIAL MYCELIUM ON STEAMED-POTATO PLUG, CULTURE 63 DAYS OLD

1-septate 1 per cent, 18.5 by 3.8 (14 to 25 by 3.5 to 4) μ.
2-septate 5 per cent, 23 by 4.1 (17 to 28 by 3.5 to 4.5) μ.
3-septate 94 per cent, 25 by 4.3 (22 to 32 by 3.5 to 5) μ.
4-septate rare, only one observed.

FROM PSEUDOPIONNOTES ON STEAMED-POTATO PLUG, CULTURE 64 DAYS OLD

1-septate 1.5 per cent, 19 by 3.8 (17 to 22 by 3.5 to 4) μ.
2-septate 2.5 per cent, 22 by 4.2 (19 to 26 by 3.8 to 4.5) μ
3-septate 96 per cent, 28 by 4.3 (21 to 32 by 3.8 to 4.5) μ.

FROM SPORODOCHIA ON IRISH POTATO AGAR WITH 10 PER CENT OF GLUCOSE, CULTURE 51 DAYS OLD

1-septate 3.5 per cent, 16 by 3.2 (12 to 26 by 2.5 to 4) μ.
2-septate 10.5 per cent, 20 by 3.9 (14 to 30 by 2.8 to 4.5) μ.
3-septate 86 per cent, 26 by 4.2 (19 to 33 by 3 to 4.8) μ.

FROM SPORODOCHIA ON STRING-BEAN AGAR, CULTURE 60 DAYS OLD

1-septate rare, only a few measured, 18 by 3 μ.
2-septate 2 per cent, 22 by 4 (16 to 29 by 2.8 to 4.5) μ.
3-septate 98 per cent, 29 by 4.5 (18 to 36 by 3 to 5) μ.
4-septate rare.

SUMMARY OF THESE MEASUREMENTS

1-septate up to 3.5 per cent, 18 by 3.5 (12 to 26 by 2.5 to 4) μ.
2-septate up to 10.5 per cent, 21 by 4 (14 to 30 by 2.8 to 5) μ.
3-septate up to 98 per cent, 27 by 4.2 (18 to 36 by 3 to 5) μ.
4-septate rare.

Fusarium nigrum, n. sp. (Pl. A, 1–4; fig. 1, J–L).

Conidia in aerial mycelium, pseudopionnotes, and sporodochia, slightly curved, somewhat abruptly constricted toward the apex, typically broader at the middle and in the upper half of their length, typically 3- and 4-septate, the 3-septate averaging 27.5 by 4.7 (18 to 38 by 3.6 to 5.9) μ, the 4-septate averaging 31 by 5 (21 to 43 by 3.6 to 6) μ; aerial mycelium typically well developed, from white to reddish brown, often nearly ox-blood red, the appearance of shades of red and brown signalizing the development of chlamydospores, on Irish potato agar with 10 per cent of glucose, various shades of red and brown, discoloring the media from amber-brown to nearly black; sclerotia-like bodies, consisting of masses of mycelium, conidia, and chlamydospores, typically pres-

ent on starchy media and steamed melilotus stems, from ox-blood red to sepia-brown and black; sporodochia salmon-orange to ochraceous-orange and buckthorn-brown (on string-bean agar). Chlamydospores, terminal and intercalary, singly and in chains and groups.

Habitat: Isolated once from Idaho soils, from group A. This organism failed to produce a decay when inoculated in potato tubers.

The measurements of the conidia on various media are as follows:

FROM AERIAL MYCELIUM ON STEAMED-POTATO PLUG, CULTURE 52 DAYS OLD

1-septate rare.
2-septate 9 per cent, 20 by 3.9 (17 to 26 by 3.6 to 4.8) μ.
3-septate 42 per cent, 30 by 5 (18 to 36 by 3.6 to 5.9) μ.
4-septate 40 per cent, 36 by 5.5 (24 to 43 by 4.2 to 6) μ.
5-septate 9 per cent, 39 by 5.6 (27 to 46 by 4.2 to 6.1) μ.
6-septate rare.

FROM AERIAL MYCELIUM ON STEAMED-POTATO PLUG, CULTURE 11 DAYS OLD

1-septate 21 per cent, 20 by 4.2 (16 to 24 by 3.5 to 4.9) μ.
2-septate 2 per cent, 22 by 4.4 (17 to 25 by 3.5 to 5) μ.
3-septate 70 per cent, 26 by 4.8 (19 to 33 by 3.9 to 5.4) μ.
4-septate 5 per cent, 27 by 5 (21 to 38 by 4 to 5.6) μ.
5-septate 2 per cent, 33 by 5.3 (24 to 41 by 4.8 to 5.8) μ.
6-septate rare.

FROM SMALL SPORODOCHIA, IN AERIAL MYCELIUM, ON STEAMED MELILOTUS STEM, CULTURE 51 DAYS OLD

2-septate 2 per cent, 20 by 4.1 (16 to 23 by 3.3 to 4.6) μ.
3-septate 65 per cent, 26 by 4.4 (20 to 33 by 3.6 to 4.7) μ.
4-septate 33 per cent, 31 by 4.9 (23 to 38 by 3.9 to 5.5) μ.
5-septate rare, 36 by 5.1 μ.

FROM SPORODOCHIA ON STRING-BEAN AGAR, CULTURE 33 DAYS OLD

2-septate 4 per cent, 22 by 4.4 (17 to 25 by 3.8 to 4.7) μ.
3-septate 56 per cent, 28 by 4.6 (22 to 38 by 3.8 to 5.2) μ.
4-septate 37 per cent, 33 by 4.7 (23 to 41 by 3.8 to 6) μ.
5-septate 3 per cent, 34 by 5.1 (23 to 44 by 3.8 to 6) μ.

SUMMARY AND AVERAGE OF THESE MEASUREMENTS

1-septate up to 21 per cent, 20 by 4.2 (16 to 24 by 3.5 to 4.9) μ.
2-septate up to 9 per cent, 22.5 by 4.2 (16 to 25 by 3.3 to 5) μ.
3-septate up to 70 per cent, 27.5 by 4.7 (18 to 38 by 3.6 to 5.9) μ.
4-septate up to 40 per cent, 31.7 by 5 (21 to 43 by 3.6 to 6) μ.
5-septate up to 9 per cent, 35.5 by 5.2 (23 to 46 by 3.8 to 6.1) μ.

SECTION MARTIELLA

Fusarium radicicola Wollenw. (*2, 11, 14, p. 257-260, pl. 6, fig. 8, text fig. 47; 21, p. 257-258, pl. 16, fig. K; 22, drawing 423*).

The organism isolated appeared to be identical with that originally described by Wollenweber (*21*) and when inoculated into potato tubers a typical blackrot was produced.

Habitat: On partly decayed tubers and roots of plants, such as *Solanum tuberosum*, in Europe and America (collected by Wollenweber) and *Ipomoea batatas* in the United States of America (collected by Harter and Field (*21*, *p. 257*).

On partly decayed tubers and roots of plants. Cause of potato dry-rot and jelly-end rot. Identified from the following: *Ipomoea batatas* (collected by Mr. L. L. Harter); *Musa sapientum* (collected by Mr. S. F. Ashby, Jamaica, Porto Rico); soil (collected by Mr. F. C. Werkenthin, Austin, Tex.) (*2*, *p. 206*).,

On rotted tubers of *Solanum tuberosum*, in Oregon, Idaho, and California (*14*, *p. 258*).

Werkenthin (*17*) in 1916 reported it from the soils of Texas. It was reported in a previous paper by the writer (*11*) as occurring on the roots of *Populus deltoides* at Jerome, Idaho, and was demonstrated to be the cause of a blackrot of the Irish potato tuber in Idaho. While on a tour of southern Arizona in November, 1915, *F. radicicola* was isolated several times from decaying roots of Egyptian cotton (*Gossypium barbadense*) and alfalfa (*Medicago sativa*) plants growing on irrigated lands in the Salt River Valley, near Phoenix, Ariz. The fungus was there found associated with a form of the rootrot of cotton and alfalfa, and the conditions under which it was found suggested that it must have entered the plant roots from the soil. It was isolated nine times from Idaho soils as follows: Once each from sample 1 and groups A and C, twice from sample 2, and four times from sample 3.

MACROSPORIUM

Macrosporium commune Rabenh.

Identified once from sample 1 and once from sample 2. This species was also once identified from decaying roots of an opuntia growing in the desert near Jerome, Idaho.

MONASCUS

A single species of the genus Monascus was once isolated from group A. It is briefly described as follows: Mycelium, white to gray; perithecia abundant, globose, black, seated on compact mass of mycelium, 15 to 18 μ in diameter; asci, one, filling the perithecium, many-spored; spores, oval to elliptical, hyalin, minute, 3 to 5 by 1 to 2 μ. Fungus in mass on steamed melilotus stem, dark-gray to black.

MUCOR

Six species of the genus Mucor were identified, and nine other unidentified forms were isolated. These nine forms apparently differed from each other and from all other species described, but it is not certain that

the differences were sufficient to justify classifying them as separate species. The species identified are as follows:

Mucor sphaerosporus Hagem, isolated twice from sample 3.

Mucor jansseni Lender, isolated three times from sample 3.

Mucor spinescens Lender, isolated once from sample 3.

Mucor circinelloides Van Tieghem, isolated once from sample 3.

Mucor botryoides Lender, isolated once from sample 3

Mucor plumbeus Benorden, isolated once from sample 2.

Nine unidentified species of Mucor, one from group A, five from group C, two from sample 2, and one from sample 4.

The species of this genus were identified by Mr. Zundel.

PENICILLIUM

A large number of Penicillium appeared in the soil cultures, and as many of these were isolated as the time available would permit. The separation of these forms into distinct strains was accomplished by Mr. Zundel, who submitted them, with some others, to Dr. Charles Thom for identification. With reference to these cultures, the following statement was prepared by Dr. Charles Thom and Miss M. B. Church, of the Microbiological Laboratory, Bureau of Chemistry:

The problem of nomenclature in Penicillium is complicated by the occurrence of numerous strains with strictly asexual fruit production (conidia production only), which have no reliable structural differences, but may show markedly different reactions in culture. The study and comparison of such series collected by us, as well as those sent to us by students in widely separated localities, have led to the conclusion advanced in the study of the *Penicillium luteum-purpurogenum* series (15) and in the study of *Aspergillus niger* (16) that there are whole groups of such saprophytes genetically so related as to differ very little in morphology, but which differ quantitatively in their activities. In culture such strains may be readily kept separate by the contrast in color reactions produced in the nutrient media used, or by the shade of color in the conidial area. In other words, this particular strain kept in pure culture under fairly uniform conditions gives approximately the same picture in successive culture over a long period of time. The chemistry of these differences is thus far unsolved. Comparison of large numbers of forms, however, separates them into series with the same range of variation in structure and reactions which appear to differ only in quantity, not in kind.

The soil cultures sent us by Mr. George L. Zundel from Jerome, Idaho, contain some interesting series, which are represented in every group of soil cultures we have received. Not all of these forms are Penicillia.

One series, No. 370, 467, 473, and 649 are cultures of Trichoderma, a genus constantly occurring in soil and soil-polluted substances. No adequate study of these forms as they occur in America has yet been made, although we have collected a large number of them as the basis for such a study.

No. 500, 504, 508, 515, with apparently accidentally admixtures in a few other cultures, prove to be a coremiform Penicillium with affinities to *P. expansum* Link. Members of this series have been examined from widely different sources. They appear to be cosmopolitan and almost omnivorous. *P. expansun*, in one or more of its forms, is the characteristic coremiform species found in the rotting of apples in

storage. In this connection many studies of its activities have been made. No adequate comparative study has yet shown the nature of the differences observable between these strains. Until such study has been made the separation of this series into species or varieties would necessarily be valueless.

No. 363 and 712 appear to be close to *P. viridicatum* Westling. The original of Westling's description was found in Sweden on roots and moldy twigs. A closely related strain from soil has since been sent us from England by Miss Dale, and similar strains from soil have come to us from widely separated States.

No. 502 is an Aspergillus for which we have yet no name to offer. This again appears in more than one series of soil cultures.

Among the very difficult Penicillia, No. 480 and 621 are probably identical members of the blue-green series; No. 452.3 suggests *P. pulitans* Westling. But by far the most interesting series in this collection is designated in Table III, the soil series, including No. 401, 447, 452.1, 597, 598, 601, 604, 606, 629, 630, 675, and 756. This lot of forms presents a series of characters which have come up repeatedly in studying

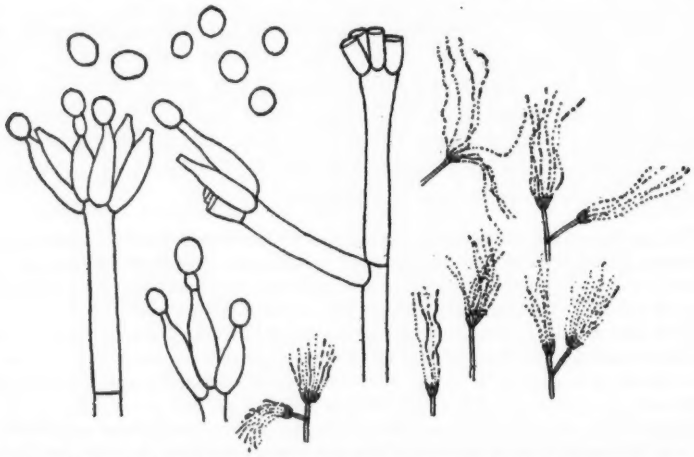

FIG. 3.—Penicillium soil series (strain 89): Colonies pale green, velvety at border, but more or less floccose in center with under side of mycelium rose to dark-red, conidia becoming globose, 2 to 3 μ in diameter. Drawn by Dr. Charles Thom.

the fungi of the soil. Similar forms have been received from Miss Dale, of England, from the soil bacteriologists of the United States Department of Agriculture, from Connecticut, and from New Jersey, and from other sources. Such forms seem to be found fairly constantly in soil cultures, but are not common in studies of foods and feeding stuffs.

Attempts to identify these forms by published descriptions were not satisfactory. Descriptions and drawings were prepared for a series of them, but these when critically compared demonstrated the close relationship of the organisms under consideration. It seemed very doubtful whether separation by such descriptions could be considered practical. The alternative is a group description drawn in broad enough terms to indicate the characteristic structure of the group with the range of variation observed. The following description is proposed:

Colonies in Czapek's solution agar white to gray, gray-green, pale-green, or pale bluish green, when old becoming various shades of gray and brown, spreading slowly but broadly with usually a wide sterile margin throughout the growing period and

slow development of colored fruit from the center outward, surface growth from velvety at the margin with center floccose to floccose out to the very edge of the colony, some strains zonate, reverse of colony at first colorless, in some strains remaining so, in others developing colors, a succession of colors appearing in series so that different strains become finally yellow, orange, orange-red, rosy, or even deep-red; the color mostly remains in the mycelium; hence, does not discolor the agar beyond the areas of immediate contact, if at all.

Odor produced, none or indefinite.

Conidiophores either rising directly from the substratum or as branches of aerial hyphæ, from very short up to 1,000 μ in length, or longer, slender mostly, 2 to 3 occasionally up to 4 μ in diameter, with walls smooth in some strains, slightly granular or roughened in others, or showing both conditions in the same culture; conidial fructifications variously branched from a single terminal verticil of sterigmata (conidiferous cells) to a verticil of metulæ (branches bearing verticils of sterigmata) including the main stalk prolonged and a single branch or a whorl of branches, more

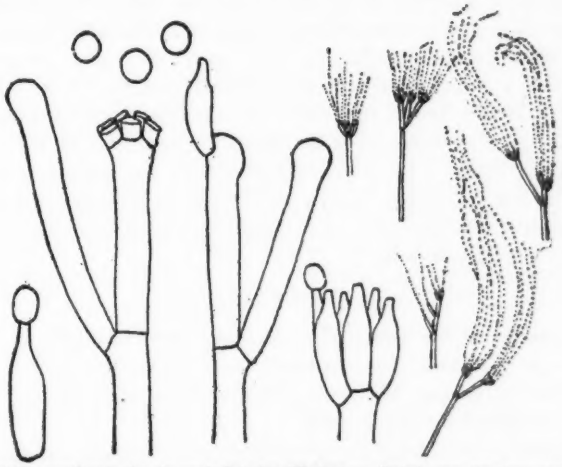

FIG. 4.—Penicillium soil series (strain 2490): Colonies differing very little in structure from strain 89 (fig. 3), but with reverse colors slowly yellow to orange. Drawn by Dr. Charles Thom.

rarely twice verticillate or partly so; sterigmata few in each verticil, mostly slender 7 to 10 by 2 to 2.5 μ, narrowing to a slender tube from which the conidia are formed. Conidia at first definitely elliptical, 1 to 2 by 2.5 μ, at first becoming 2.5 μ in diameter or even 3 to 3.5 μ in age, continuing elliptical or becoming almost globose, either smooth or delicately roughened or both conditions in the same strain (fig. 3, 4).

Habitat: Soils.

PERICONIA

Periconia byssoides Pers.

Isolated four times from Idaho soils, once from sample 3, once from group A, and twice from group B. Identified by Mr. Zundel.

RHIZOPUS

Rhizopus nigricans Ehr.

Isolated once from group C. Identified by Mr. Zundel.

RHIZOCTONIA

Rhizoctonia solani Kühn.

Identified five times from Idaho soils, twice from group A, once from sample 1, and twice from sample 3. Considerable difficulty was experienced in placing this organism in pure culture. This was accomplished but once, in one isolation from group A. The identification was made certain by a careful comparison with authentic cultures of *R. solani*. The other four identifications were made by a careful study of the mycelial and sclerotial characters, though the fungus was mixed in culture with other fungi, principally species of Fusarium.

Habitat: *R. solani* Kühn. has been reported from a great number of hosts, including the potato, from the soil and from decaying vegetable matter in the soil in humid regions. Cause of russet-scab of the potato and reported to be the cause of other potato disorders, including potato-rosette, aerial tubers, stemblight, damping-off of young potato plants, etc. Cause of damping-off of many economic plants. A complete host index is too long to be included here. A host index and historical sketch was published in 1916 in a work by Peltier (7), who isolated the organism from Illinois soils. The writer has identified the organism from the roots of alfalfa (*Medicago sativa*), sagebrush (*Artemesia tridentata*) and rabbit-brush (*Chrysothamnus graveolens*) in southern Idaho. Isolated five times from Idaho soils.

STEMPHYLIUM

Two species of the genus Stemphylium were isolated, as follows: *Stemphylium piriforme* Bos., isolated three times from group A; and *Stemphylium paxianum* V. Szabo., isolated once each from groups A and B. Identified by Mr. Zundel.

THAMNIDIUM

Thamnidium elegans Link., isolated once each from samples 2 and 3. Identified by Mr. Zundel.

TRICHODERMA

Four forms of the genus Trichoderma were isolated as follows: Twice from group C and once each from samples 1 and 2. (See statement by Dr. Thom, p. 93.) Identified by Dr. Charles Thom.

TORULA

One species of the genus Torula was isolated, once from group B and once each from samples 1, 2, and 3. This species is briefly described as follows:

Hyphæ dark, olivaceous, black in mass, septate; conidiophores simple; conidia in chains, unicellular, subglobose to ellipsoidal, olivaceous, black in mass, 8 to 15 by 6 to 8 μ.

VERTICILLIUM

Five species of the genus Verticillium were isolated, referred to in Table III by No. 419, 477, 603, 771, and 825. No. 419 was isolated twice from sample 1; No. 477 once each from samples 1 and 3; No. 603 once from sample 5; No. 771 once from group C; and No. 825 once each from sample 1 and groups A and C. No. 771 proved interesting in that it was once isolated from the discolored vascular bundles of a potato tuber grown in plot 11 (1916) on virgin desert soil, near Aberdeen, Idaho. This species is briefly described as follows: Conidia oval to elliptical, 2.5 to 8 by 1 to 3 μ, in chains on branches in verticillate whorls; mycelium and spores, in mass, from brick-red to dark reddish brown, on such media as steamed-potato plugs, steamed rice, and agars containing glucose.

STERILE MYCELIA

A sterile mycelium, reddish brown in color, was once isolated from sample 5, a sterile white form, apparently the same in each case was 20 times isolated, 8 times from sample 1, 4 times from sample 2, once from sample 3, 5 times from group A, and once each from each of groups C and D. A pink form was isolated once from sample 2 and twice from group A. At first it was thought that this pink form might be a species of Fusarium, which for some reason was slow in fruiting; but after nearly a year's growth in culture, no fruiting bodies were produced. A buff-colored form producing brownish to pinkish brown sclerotia-like bodies was once isolated from group A, and a yellowish form isolated once from sample 5.

SIGNIFICANCE OF THE INVESTIGATIONS

The special significance of these investigations lies in the finding of parasitic fungi in desert soils, on wild plants growing in the desert, and on cultivated plants in arid regions, where it is probable that the infection proceeded from the soil. These desert soils have commonly been supposed to support only a scant fungus flora and to be free from organisms of a parasitic nature. Their known presence in the soil, it is believed, explains the appearance of disease in the product of disease-free seed potatoes planted on new land and suggests that whenever it is attempted to grow disease-free potatoes, the rôle played by soil fungi must be taken into consideration.

SUMMARY

(1) Fungus forms were found to be abundant in desert soils.

(2) Three fungi, *Fusarium radicicola* Wollenw., *Fusarium trichothecioides* Wollenw., and *Rhizoctonia solani* Kühn., known to be parasitic on the Irish potato were isolated from Idaho soils never cropped with potatoes.

(3) Plantings of disease-free seed potatoes on new lands in southern Idaho failed to yield a disease-free product.

(4) The presence of parasitic fungi in these soils suggests that infection in potatoes may often originate with soil organisms.

(5) The results obtained from planting disease-free seed potatoes on cultivated lands never in potatoes, and on virgin desert land further substantiate the opinion that land, previously cropped with such crops as alfalfa, clover, and grain, is better adapted to the production of disease-free potatoes than virgin desert land.

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EXPLANATION OF PLATES A AND B

Plates A and B are reproductions of water-color drawings of cultures grown in the light at ordinary room temperatures, ranging from 16° to 26° C., in the laboratories of the U. S. Department of Agriculture at Washington, D. C. When grown under similar conditions in the arid West, the colors are often not so pronounced, owing probably to the earlier drying out of the media. It has also been noted that, when the cultures are grown at temperatures ranging from 30° to 42° C., the normal shades of red may be entirely wanting and in their stead dirty yellows and browns may appear. In text figures 1 and 2 attempt has been made to reproduce typical conidial and other spore forms by which the fungi might be identified at any stage of their growth on any of the media employed, such as steamed rice, steamed-potato plugs, steamed melilotus stems, Irish potato agar with 10 per cent of glucose added, and string-bean agar.

PLATE A

1–4.—*Fusarium nigrum*, n. sp.:

1. Culture 32 days old on steamed Irish potato plug.
2. Culture 40 days old on string-bean agar.
3. Culture 21 days old on steamed rice.
4. Culture 31 days old on Irish potato agar, plus 10 per cent of glucose. Note the nearly black color of the medium at the bottom of the tube, left-hand side.

5–6.—*Fusarium elegantum*, n. sp.:

5. Culture 25 days old on steamed rice.
6. Culture 18 days old on steamed-potato plug.

7–8.—*Fusarium lanceolatum*, n. sp.:

7. Culture 20 days old on steamed-potato plug.
8. Culture 18 days old on steamed rice.

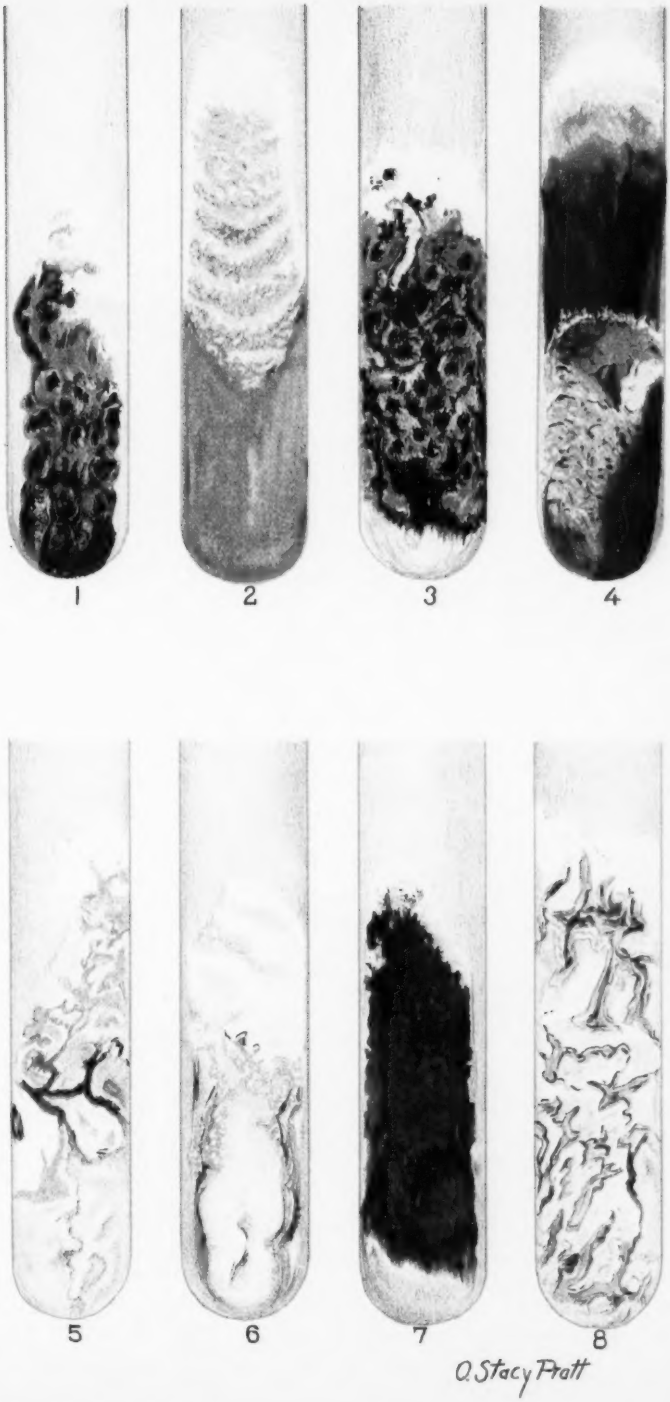

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PLATE B

1–3.—*Fusarium aridum*, n. sp.:

1. Culture 40 days old on string-bean agar.
2. Culture 31 days old on steamed-potato plug.
3. Culture 17 days old on steamed rice.

4–6.—*Fusarium idahoanum*, n. sp.:

4. Culture 41 days old on Irish potato agar with 10 per cent of glucose added.
5. Culture 20 days old on steamed-potato plug.
6. Culture 21 days old on steamed rice.

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INVESTIGATIONS CONCERNING THE SOURCES AND CHANNELS OF INFECTION IN HOG CHOLERA

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INTRODUCTION

In hog cholera, as in other infectious diseases, the success of control measures is largely dependent upon a knowledge of the channels through which the infection is conveyed. Without such knowledge, or without the ability to close the avenues of transmission, if they are known, control by sanitation can not succeed. It is commonly known that hogs affected with cholera will transmit the disease to the nonimmunes which are allowed to associate with them. It is further known that pens or lots in which hogs sick of cholera have been kept are likely to harbor the infection, and that healthy hogs placed in such lots are liable to contract the disease. Many years ago, in a report issued by the Bureau of Animal Industry,[1] the sources and channels of infection were enumerated as follows:

(a) Pigs purchased from infected herds, or coming in contact with those from infected farms, or running over grounds occupied by diseased swine within two or three months.

(b) Infected streams may communicate the disease to herds below the source of infection.

(c) Virus may be carried in feed, implements, and on the feet and clothing of persons from infected herds and premises.

(d) Winds, insects, birds (particularly buzzards), and various animals may transport hog-cholera virus.

This statement of the ways in which hog cholera is spread forms the basis for our present-day sanitary regulations. It has seemed to the writers that perhaps in actual practice one or more of these channels of infection may be of preponderating importance, and that the determination of such a fact would greatly simplify the difficult problem of sanitary control. Although the experiments of the writers are not yet complete, sufficient data have been secured to make it desirable to render this report of progress, and it is hoped that others may undertake similar investigations. Conditions in nature are so variable that a single series of experiments can hardly yield results that would serve as a guide in practice in different localities under diverse climatic conditions.

[1] Hog cholera, its history, nature, and treatment. U. S. Dept. Agr. Dept. Rpt. 46, p. 123. 1889.

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TRANSMISSION OF HOG CHOLERA BY PIGS

The fact that the blood and excreta and the eye secretions of hogs sick of cholera contain the virus of the disease is already well established. However, comparatively little systematic work has been done to ascertain whether the virus is discharged from the body only at certain stages or whether this occurs continuously throughout the course of the disease. Experiments on this point have been carried out in two groups. In the first, the pathogenic power of the blood, urine, feces, eye secretions, and nose secretions from hogs in different stages of the disease was determined (1) by the inoculation of susceptible pigs, (2) by feeding susceptible pigs with the secretions and excreta, and (3) by scattering the secretions and excreta in pens containing susceptible pigs. In the second group of experiments the contagiousness of the disease at different stages was determined by placing susceptible pigs in contact with those that were infected.

INFECTIOUSNESS OF THE BLOOD, EXCRETA, AND SECRETIONS OF CHOLERA-INFECTED PIGS

EXPERIMENT I.—Pig 1032x was injected subcutaneously with 5 c. c. of virus blood on October 11, 1916. This pig showed a rise of temperature on the fourth day, and the first visible symptoms were observed on the fifth day. The animal died on the tenth day, exhibiting well-marked hemorrhagic lesions at autopsy.

The clinical record of pig 1032x is given in Table I.

TABLE I.—*Record of pig 1032x*

Date.	Temperature.	Symptoms.
1916.	°F.	
October 11	.....	Normal. Injected this day.
October 13[a]	103.0	Normal.
October 12[a]	103.8	Do.
October 14[a]	103.8	Do.
October 15	104.9	Do.
October 16[a]	105.0	Sluggish.
October 17	105.8	Off feed.
October 18	107.2	Do.
October 19	107.0	Off feed; slight diarrhea.
October 20[a]	106.0	Off feed; profuse diarrhea.
October 21	.....	Dead.

[a] Blood, excreta, and secretions were tested on these dates.

On the first, second, third, fifth, and ninth days after injection the blood, urine, and feces, and the eye and nose secretions were collected and tested on susceptible pigs. Two pigs were injected with each material on each date, making a total of 10 pigs injected on each day.

The blood was obtained by bleeding from the tail. The urine and feces were collected in sterile bottles. The eye and nose secretions were

obtained on sterile cotton swabs, each swab being immediately rubbed up in 10 c. c. of sterile salt solution. The feces were shaken up in sterile salt solution, and the coarse particles were allowed to settle before injecting; the rather thick suspension was filtered through gauze and administered in doses of 10 c. c. The material was administered to the susceptible pigs in each instance by subcutaneous inoculation.

The results of this experiment are shown in detail in Table II.

This experiment shows that the blood and urine were virulent on the first day after injection, the feces on the second day, while the eye and nose secretions were virulent on the third day. As the pig which furnished the test materials did not develop fever until the fourth day and exhibited no visible symptoms until the fifth day, the experiment shows that the virus circulated in the body of the cholera-infected pig before the onset of fever and before the development of any visible symptoms. It is clear also that the virus was thrown off in the excreta and secretions during this time.

TABLE II.—*Results of Experiment I on infectiousness of blood, excreta, and secretions of infected pigs*

MATERIALS COLLECTED AND INJECTED ON OCTOBER 12, 1916 (FIRST DAY)

Pig No.	Weight.	Material injected.	Result.
	Pounds.		
1033X	40	5 c. c. of tail blood	Died October 28. Cholera lesions.
1034	55	.....do	Do.
[a]1035	45	5 c. c. of eye-swab dilution	Remained well.
[a]1036	65	.....do	Do.
[a]1037	45	5 c. c. of nose-swab dilution	Do.
[a]1038	70	.....do	Do.
1041	40	5 c. c. of urine	Sick October 20–24. Recovered.
1042	65	.....do	Do.
1039	40	10 c. c. of fecal suspension	Remained well.
1040	55	.....do	Do.

MATERIALS COLLECTED AND INJECTED ON OCTOBER 13, 1916 (SECOND DAY)

1043	40	5 c. c. of tail blood	Died October 30. Cholera lesions.
1044	55	.....do	Do.
[a]1051	35	5 c. c. of eye-swab dilution	Remained well.
[a]1052	65	.....do	Do.
[a]1049	40	5 c. c. of nose-swab dilution	Do.
[a]1050	55	.....do	Do.
1045	35	5 c. c. of urine	Killed in moribund condition November 14. Cholera lesions.
1046	60	.....do	Sick October 24 to November 17. Recovered.
1047	35	15 c. c. of fecal suspension	Killed in moribund condition November 14. Cholera lesions.
1048	55	.....do	Died November 12. Cholera lesions.

[a] These pigs were subsequently infected with virus blood to test their immunity and all developed typical hog cholera except 1038 and 1052. Pig 1038 suffered no ill effects from the virus infection and evidently possessed a high degree of natural immunity. Pig 1052 showed a temperature reaction following the virus injection but no visible symptoms.

TABLE II.—*Results of Experiment I on infectiousness of blood, excreta, and secretions of infected pigs*—Continued

MATERIALS COLLECTED AND INJECTED ON OCTOBER 14, 1916 (THIRD DAY)

Pig No.	Weight.	Material injected.	Result.
	Pounds.		
1053	40	5 c. c. of tail blood	Died October 27. Cholera lesions.
1054	70	do	Died October 30. Cholera lesions.
1055	40	5 c. c. of eye-swab dilution	Died November 7. Cholera lesions.
1056	65	do	Killed in moribund condition November 7. Cholera lesions.
[a]1057	45	5 c. c. of nose-swab dilution	Remained well.
1058	60	do	Sick October 23–30. Recovered.
1061	35	5 c. c. of urine	Died October 26. Cholera lesions.
1062	60	do	Died October 27. Cholera lesions.
1059	35	10 c. c. of fecal suspension	Died November 10. Cholera lesions.
1060	50	do	Killed in moribund condition November 10. Cholera lesions.

MATERIALS COLLECTED AND INJECTED ON OCTOBER 16, 1916 (FIFTH DAY)

1073	35	5 c. c. of tail blood	Died November 30. Cholera lesions.
1074	55	do	Sick October 21 to November 2. Recovered.
1071	35	5 c. c. of eye-swab dilution	Died November 3. Cholera lesions.
1072	60	do	Killed in moribund condition October 30. Cholera lesions.
1069	35	5 c. c. of nose-swab dilution	Died November 1. Cholera lesions.
1070	65	do	Sick October 21 to November 27. Recovered.
1065	35	5 c. c. of urine	Killed in moribund condition October 31. Cholera lesions.
1066	60	do	Died October 30. Cholera lesions.
1067	40	10 c. c. of fecal suspension	Killed in moribund condition October 31. Cholera lesions.
1068	65	do	Died October 26. Cholera lesions.

MATERIALS COLLECTED AND INJECTED ON OCTOBER 20, 1916 (NINTH DAY)

1081	30	2 c. c. of tail blood	Died October 31. Cholera lesions.
1082	55	do	Died October 30. Cholera lesions.
1085	30	5 c. c. of eye-swab dilution	Killed in moribund condition October 31. Cholera lesions.
1086	55	do	Do.
1083	50	5 c. c. of nose-swab dilution	Died November 7. Cholera lesions.
1084	30	do	Killed in moribund condition November 13. Cholera lesions.
1079	30	5 c. c. of urine	Do.
1080	45	do	Died November 6. Cholera lesions.
1087	50	10 c. c. of fecal suspension	Died October 26. Cholera lesions.
1088	25	do	Died October 27. Cholera lesions.

[a] This pig was subsequently injected with virus blood to test its immunity and developed typical hog cholera.

EXPERIMENT II.—In this experiment, which was begun on June 28, 1917, the eye and nose secretions, urine, and feces were collected from a cholera-infected pig (No. 427), which received an injection of 5 c. c.

of virus blood on June 25. This pig showed a fever temperature on June 28, was off feed on June 29, showed weakness and conjunctivitis on June 30, and died on July 11, showing well-marked hemorrhagic lesions at autopsy. The secretions and excreta were collected on the third, fifth, and seventh days after the virus injection—that is, on June 28, June 30, and July 2, 1917.

The eye and nose secretions were collected on sterile cotton swabs. The urine and feces were collected in wide-mouth sterile bottles, the excreta being collected as they were passed by the pig. The eye and nose swab dilutions were prepared by washing off the cotton swabs contaminated with the secretions in 60 c. c. of normal salt solution. The urine was diluted with an equal volume of salt solution. The fecal suspension used on the third and fifth days was prepared by shaking up approximately 100 gm. of feces in 300 c. c. of salt solution. On the seventh day 50 gm. of feces to 300 c. c. of salt solution was used. The secretions and excreta were tested on susceptible pigs within a few hours after they were collected.

On each of the days on which the secretions and excreta were collected, two susceptible pigs were injected with 5 c. c. each of an eye-swab dilution, two with 5 c. c. each of a nose-swab dilution, two with 5 c. c. each of urine, and two with 10 c. c. each of fecal suspension.

On the first day on which the secretions and excreta were collected, two pigs were fed with 25 c. c. each of eye-swab dilution, two with 25 c. c. each of nose-swab dilution, two with 5 c. c. each of urine, and two with 10 c. c. each of the fecal suspension. The materials were mixed with slop when fed. The same pigs were fed with the same doses on each of the succeeding days on which materials were collected. These pigs therefore received three feedings of supposedly infectious materials.

On each of the three days on which the secretions and excreta were collected 25 c. c. of a freshly prepared eye-swab dilution were scattered on the floor of a pen containing two susceptible pigs, while 25 c. c. of a freshly prepared nose-swab dilution were scattered in a second pen containing two pigs. In a third pen containing two susceptible pigs freshly collected urine was scattered as follows: On the third day 50 c. c., on the fifth day 140 c. c., and on the seventh day 130 c. c. In a fourth pen containing two pigs about 360 c. c. of freshly prepared fecal suspension were scattered on the third, fifth, and seventh days. The same pigs were thus exposed in a similar manner to the supposedly infectious materials on each of the days upon which these materials were collected.

The results obtained in this experiment were briefly as follows:

The eye and nose secretions and the feces collected on the third day were infectious when injected. The urine collected on this day was not infectious when injected.

The eye and nose secretions, the urine, and the feces collected on the fifth and seventh days were all infectious when injected.

The eye and nose secretions, the urine and the feces, collected on the third, fifth, and seventh days proved to be noninfectious when fed and when scattered in the pens.

The results of this experiment are shown in detail in Table III.

TABLE III.—*Results of Experiment II on the infectiousness of blood excreta, and secretions of infected pigs*

MATERIALS COLLECTED AND INJECTED ON JUNE 28, 1917 (THIRD DAY)

Pig No.	Weight.	Material injected.	Result.
	Pounds.		
444	55	5 c. c. of eye-swab dilution	Died July 16. Cholera lesions.
445	40	do	Killed in moribund condition July 16. Cholera lesions.
446	55	5 c. c. of nose-swab dilution	Died July 15. Cholera lesions.
447	40	do	Died July 19. Cholera lesions.
[a]448	55	10 c. c. of diluted urine	Remained well.
[a]449	50	do	Do.
450	30	10 c. c. of fecal suspension	Sick July 5 to 17; cholera symptoms. Recovered.
451	30	10 c. c. of fecal suspension	Died July 18. Cholera lesions.

MATERIALS COLLECTED AND INJECTED ON JUNE 30, 1917 (FIFTH DAY)

503	40	5 c. c. of eye-swab dilution	Killed in moribund condition July 19. Cholera lesions.
504	60	do	Do.
505	50	5 c. c. of nose-swab dilution	Killed in moribund condition July 23. Cholera lesions.
506	50	do	
507	40	10 c. c. of diluted urine	Died July 16. Cholera lesions.
508	65	do	Killed in moribund condition July 16. Cholera lesions.
509	40	10 c. c. of fecal suspension	Killed in emaciated condition July 26. Cholera lesions.
510	40	do	Killed in emaciated condition July 27. Cholera lesions.

MATERIALS COLLECTED AND INJECTED ON JULY 2, 1917 (SEVENTH DAY)

515	40	5 c. c. of eye-swab dilution	Killed in moribund condition July 19. Cholera lesions.
516	40	do	Do.
517	40	5 c. c. of nose-swab dilution	Killed in moribund condition July 20. Cholera lesions.
518	40	do	Do.
519	40	10 c. c. of diluted urine	Do.
520	50	do	Do.
521	45	10 c. c. of fecal suspension	Do.
522	45	do	Killed in moribund condition July 19. Cholera lesions.

[a] These pigs were subsequently exposed to hog cholera by injections of virus blood, and all proved to be susceptible.

TABLE III.—*Results of Experiment II on the infectiousness of blood excreta, and secretions of infected pigs*—Continued

MATERIALS COLLECTED AND FED ON JUNE 28, JUNE 30, AND JULY 2, 1917 (THIRD, FIFTH, AND SEVENTH DAYS)

Pig No.	Weight.	Material injected.	Result.
	Pounds.		
[a] 452	60	25 c. c. of eye-swab dilution...	Remained well.
[a] 453	55	.....do.....	Do.
[a] 454	40	25 c. c. of nose-swab dilution....	Do.
[a] 455	40	.....do.....	Do.
[a] 456	50	10 c. c. of diluted urine.....	Do.
[a] 457	45	.....do.....	Do.
[a] 458	60	10 c. c. of fecal suspension.....	Do.
[a] 459	45	.....do.....	Do.

MATERIALS COLLECTED AND SCATTERED IN PENS ON JUNE 28, JUNE 30, AND JULY 2, 1917 (THIRD, FIFTH, AND SEVENTH DAYS)

[a] 460	50	25 c. c. of eye-swab dilution...	Remained well.
[a] 461	60	.....do.....	Do.
[a] 462	45	25 c. c. of nose-swab dilution....	Do.
[a] 463	50	.....do.....	Do.
[a] 464	55	50 c. c., 140 c. c., and 130 c. c. of urine.	Do.
[a] 465	55	.....do.....	Do.
[a] 466	45	360 c. c. of fecal suspension....	Do.
[a] 467	45	.....do.....	Do.

[a] These pigs were subsequently exposed to hog cholera by injections of virous blood and all proved to be susceptible.

EXPERIMENT III.—In this experiment, which was begun on August 2, 1917, the blood, eye and nose secretions, urine, and feces were collected from a cholera-infected pig on the seventh day after injection. Pig 2226, which furnished the blood, secretions, and excreta, was injected with virus on July 26, 1917. This pig went off feed on July 30, showed conjunctivitis, diarrhea, and weakness on August 2, and died on August 3, exhibiting extensive hemorrhagic lesions at autopsy.

The blood was obtained by bleeding from the tail, and was defibrinated and strained through sterile gauze. The secretions and excreta were collected in the same manner as in Experiment II. The blood, secretions, and excreta were tested when fresh—that is, within a short time after they were collected, and were also tested after being held for 24 and 48 hours at room temperature (72° to 85° F.).

In collecting the eye secretions, three swabs were taken from the eyes. One of these, soon after collection, was rubbed up in 35 c. c. of normal salt solution and two pigs were injected with 15 c. c. each of the suspension. The two other swabs were held at room temperature. At the end of 24 hours a second swab was rubbed up in 35 c. c. of salt solution and two pigs injected with 15 c. c. each of the resulting suspension. At

the end of 48 hours the third swab was rubbed up in 35 c. c. of salt solution and two pigs injected, as before, with 15 c. c. each.

Three nose swabs were prepared and tested in the same manner as the eye swabs. The urine was used undiluted. In testing the feces, which were diarrheal in character, about 5.5 gm. of the feces were shaken up in 40 c. c. of normal salt solution and filtered through sterile gauze; susceptible pigs were given 15 c. c. each of this suspension.

After standing at room temperature for 24 hours, the blood had darkened but had a normal odor. The secretions on the eye and nose swabs had become dry. The urine had not changed in appearance The feces had become darker in color and drier.

After standing at room temperature for 48 hours, the blood was quite dark in color and had a putrid odor. The urine showed a sediment and had a stale odor. The feces were darker and had a putrid odor.

The results obtained in this experiment were briefly as follows:

When injected fresh, the blood, secretions, and excreta obtained on the seventh day were all infectious.

When injected after being held for 24 hours at room temperature, the blood, secretions, and excreta were still infectious.

When injected after being held for 48 hours at room temperature, the blood, urine, and feces remained infectious, but the eye and nose secretions were no longer infectious.

The detailed results of this experiment are shown in Table IV.

TABLE IV.—*Results of Experiment III on the infectiousness of blood, excreta, and secretions of infected pigs*

MATERIALS COLLECTED AND INJECTED ON AUGUST 2, 1917 (SEVENTH DAY)

Pig No.	Weight.	Material injected.	Result.
	Pounds.		
590	75	5 c. c. of tail blood	Died August 12. Cholera lesions.
591	75	.....do	Died August 16. Cholera lesions.
592	70	15 c. c. of eye-swab dilution	Do.
593	70	.....do	Killed in moribund condition August 20. Cholera lesions.
594	70	15 c. c. of nose-swab dilution	Died August 20. Cholera lesions.
595	70	.....do	Died August 19. Cholera lesions.
596	75	5 c. c. of urine	Died August 18. Cholera lesions.
597	75	.....do	Died August 19. Cholera lesions.
598	70	15 c. c. of fecal suspension	Died August 9. Cholera lesions.
599	70	.....do	Do.

TABLE IV.—*Results of Experiment III on the infectiousness of blood, excreta, and secretions of infected pigs*—Continued

MATERIALS COLLECTED ON AUGUST 2, 1917, AND INJECTED ON AUGUST 3, 1917 (HELD FOR 24 HOURS AT ROOM TEMPERATURE)

Pig No.	Weight.	Material injected.	Result.
	Pounds.		
600	70	2 c. c. of tail blood	Killed in moribund condition August 16. Cholera lesions.
601	70	.....do	Died August 15. Cholera lesions.
602	65	15 c. c. of eye-swab dilution	Died August 16. Cholera lesions.
603	65	.....do	Died August 19. Cholera lesions.
604	70	15 c. c. of nose-swab dilution	Killed in moribund condition August 20. Cholera lesions.
605	70	.....do	Do.
606	70	5 c. c. of urine	Died August 16. Cholera lesions.
607	70	.....do	Do.
608	70	15 c. c. of fecal suspension	Died August 11. Cholera lesions.
609	70	.....do	Died August 10. Cholera lesions.

MATERIALS COLLECTED AUGUST 2, 1917, AND INJECTED ON AUGUST 4, 1917 (HELD FOR 48 HOURS AT ROOM TEMPERATURE)

612	70	2 c. c. of tail blood	Died August 12. Cholera lesions.
613	70	.....do	Died August 13. Cholera lesions.
[a]614	70	15 c. c. of eye-swab dilution	Remained well.
[a]615	70	.....do	Do.
[a]616	60	15 c. c. of nose-swab dilution	Do.
[a]617	60	.....do	Do.
618	65	5 c. c. of urine	Died August 15. Cholera lesions.
619	65	.....do	Killed in moribund condition August 15. Cholera lesions.
620	70	15 c. c. of fecal suspension	Died August 11. Cholera lesions.
621	70	.....do	Do.

[a] These pigs were subsequently injected with virus blood to test their immunity, and as a result all developed hog cholera.

EXPERIMENT IV.—In this experiment, which was begun on September 21, 1917, the eye and nose secretions, urine, and feces of a pig infected by virus injection were collected on the second, third, fifth, and seventh days after injection. Pig 669, which furnished the secretions and excreta for this experiment, received an injection of virus blood on September 19. This pig showed a fever temperature on September 24, was off feed on September 26, developed diarrhea and purple skin, and died on October 3, showing extensive hemorrhagic lesions at autopsy.

The eye and nose secretions were collected on sterile cotton swabs, each of which was washed off in 25 c. c. of sterile normal salt solution. The urine and feces were collected in the same manner as in the preceding experiments. The urine was used undiluted. A suspension of the fecal matter was made with normal salt solution, using 5 gm. to 50 c. c. of the salt solution, which was then strained through sterile gauze. In all instances, unless otherwise stated, the materials were freshly prepared and used within a short time after they were collected.

On each of the days on which the above materials were collected, two pigs were injected with 10 c. c. each of the eye-swab dilution, two with 10 c. c. each of the nose-swab dilution, two with 5 c. c. each of urine, and two with 20 c. c. each of the fecal suspension.

On the first day on which materials were collected, two pigs were fed 10 c. c. each of the eye swab dilution, two were fed with 10 c. c. each of nose swab dilution, two with 5 c. c. each of urine, and two with a suspension of 2.5 gms. of fecal matter. The materials in each instance were fed in the slop. The same pigs were fed with the same doses on each of the succeeding days on which the materials were collected. These pigs, therefore, received four feedings of supposedly infectious materials.

On the first day on which materials were collected 20 c. c. of eye-swab dilution were scattered over the floor of a pen containing two pigs, 20 c. c. of nose-swab dilution were scattered in a second pen containing two pigs, 200 c. c. of urine were scattered in a third pen containing two pigs, and 30 gm. of feces suspended in salt solution were scattered in a fourth pen containing two pigs. The same pigs were exposed in a similar manner to similar amounts of supposedly infectious materials on each of the succeeding days upon which these materials were collected. This set of pigs was exposed, therefore, on four days to supposedly infectious materials scattered in their pens.

The materials collected on the fifth day were also held at room temperature, varying from 60° to 80° F., for 24 hours, and injected in the same doses as when injected fresh.

The materials collected on the seventh day were held at room temperature, varying from 60° to 75° F., for 24 and 48 hours, and injected in the same doses as when injected fresh. The eye- and nose-swab dilutions at the end of 48 hours remained neutral, the urine became slightly more acid, and the feces, which were neutral when collected, became slightly acid.

The results obtained in this experiment were briefly as follows:

The freshly collected secretions and excreta obtained on the second day proved to be noninfectious when injected.

The freshly collected secretions and excreta obtained on the third day were all infectious when injected, except the urine, which proved to be noninfectious.

The freshly collected secretions and excreta obtained on the fifth and seventh days were all infectious when injected.

The freshly collected secretions and excreta proved to be noninfectious when fed, with the possible exception of one pig fed with eye-swab dilution. This pig developed hog cholera 23 days after the date of last feeding.

The freshly collected secretions and excreta also proved to be noninfectious when scattered in the pens, with the exception of one pen

where the nasal secretion was scattered. In this pen one pig sickened 16 days after the date on which nasal secretion was last scattered in the pen.

The secretions and excreta obtained on the fifth day and held at room temperature for 24 hours were all infectious.

The secretions and excreta obtained on the seventh day and held at room temperature for 24 hours were all infectious.

In the case of the secretions and excreta obtained on the seventh day and held at room temperature for 48 hours, the urine and feces were infectious, while the eye and nose secretions proved to be no longer infectious.

The results of this experiment are shown in detail in Table V.

TABLE V.—*Results of Experiment IV on the infectiousness of blood, excreta, and secretions of infected pigs*

Pig No.	Weight.	Material injected.	Result.
	Pounds.		
MATERIALS COLLECTED AND INJECTED ON SEPTEMBER 21, 1917 (SECOND DAY)			
[a] 737	65	10 c. c. of eye-swab dilution	Remained well.
[a] 738	50	do	Do.
[a] 739	55	10 c. c. of nose-swab dilution	Do.
[a] 740	60	do	Do.
[a] 741	65	5 c. c. of urine	Do.
[a] 742	45	do	Do.
[a] 743	45	20 c. c. of fecal suspension	Do.
[a] 744	60	do	Do.
MATERIALS COLLECTED AND INJECTED ON SEPTEMBER 22, 1917 (THIRD DAY)			
761	55	10 c. c. of eye-swab dilution	Died October 9. Cholera lesions.
762	55	do	Died October 12. Cholera lesions.
763	70	10 c. c. of nose-swab dilution	Died October 9. Cholera lesions.
[a] 764	50	do	Remained well.
[a] 765	45	5 c. c. of urine	Do.
[a] 766	65	do	Do.
767	50	20 c. c. of fecal suspension	Died October 4. Cholera lesions.
768	60	do	Died October 12. Cholera lesions.
MATERIALS COLLECTED AND INJECTED SEPTEMBER 24, 1917 (FIFTH DAY)			
769	65	10 c. c. of eye-swab dilution	Died October 12. Cholera lesions.
770	55	do	Do.
771	60	10 c. c. of nose-swab dilution	Died October 10. Cholera lesions.
772	50	do	Died October 8. Cholera lesions.
773	50	5 c. c. of urine	Died October 12. Cholera lesions.
774	50	do	Killed in moribund condition October 12. Cholera lesions.
775	65	20 c. c. of fecal suspension	Died October 10. Cholera lesions.
776	50	do	Do.

[a] These pigs were subsequently exposed to hog cholera by virus injections to test their immunity and all developed cholera except pigs No. 764, which remained well and probably possessed considerable natural immunity.

TABLE V.—*Results of Experiment IV on the infectiousness of blood, excreta, and secretions of infected pigs*—Continued

MATERIALS COLLECTED AND INJECTED ON SEPTEMBER 26, 1917 (SEVENTH DAY)

Pig No.	Weight.	Material injected.	Result.
	Pounds.		
785	40	10 c. c. of eye-swab dilution...	Died October 8. Cholera lesions.
786	40	.....do.....	Killed in emaciated condition November 12. Cholera lesions.
787	65	10 c. c. of nose-swab dilution...	Died October 13. Cholera lesions.
788	40	.....do.....	Do.
789	65	5 c. c. of urine.....	Do.
790	45	.....do.....	Do.
791	70	20 c. c. of fecal suspension.....	Died October 11. Cholera lesions.
792	45	.....do.....	Do.

MATERIALS COLLECTED ON SEPTEMBER 24 (FIFTH DAY) AND INJECTED ON SEPTEMBER 25, 1917 (HELD FOR 24 HOURS AT ROOM TEMPERATURE)

777	30	10 c. c. of eye-swab dilution....	Died November 5. Cholera lesions.
778	55	.....do.....	Sickened October 19. Developed chronic hog cholera.
779	40	10 c. c. of nose-swab dilution...	Died October 25. Cholera lesions.
780	60	.....do.....	Died November 3. Cholera lesions.
781	45	5 c. c. of urine.....	Died October 12. Cholera lesions.
782	65	.....do.....	Do.
783	35	20 c. c. of fecal suspension.....	Died October 11. Cholera lesions.
784	50	.....do.....	Do.

MATERIALS COLLECTED ON SEPTEMBER 26 (SEVENTH DAY) AND INJECTED ON SEPTEMBER 27, 1917 (HELD FOR 24 HOURS AT ROOM TEMPERATURE)

793	60	10 c. c. of eye-swab dilution....	Died October 17. Cholera lesions.
794	80	.....do.....	Do.
795	50	10 c. c. of nose-swab dilution...	Killed in emaciated condition November 12. Cholera lesions.
796	70	.....do.....	Sickened, but recovered.
797	80	5 c. c. of urine.....	Died October 19. Cholera lesions.
798	60	.....do.....	Do.
799	45	20 c. c. of fecal suspension.....	Died October 14. Cholera lesions.
800	50	.....do.....	Developed chronic hog cholera.

MATERIALS COLLECTED ON SEPTEMBER 26 (SEVENTH DAY) AND INJECTED ON SEPTEMBER 28, 1917 (HELD FOR 48 HOURS AT ROOM TEMPERATURE)

[a] 801	60	10 c. c. of eye-swab dilution...	Remained well.
[a] 802	65	.....do.....	Do.
[a] 803	60	10 c. c. of nose-swab dilution...	Do.
[a] 804	60	.....do.....	Do.
805	65	5 c. c. of urine.....	Died October 16. Cholera lesions.
806	60	.....do.....	Do.
807	65	20 c. c. of fecal suspension.....	Do.
808	55	.....do.....	Died October 15. Cholera lesions.

[a] These pigs were subsequently exposed to hog cholera by virus injections to test their immunity and all developed cholera except pigs Nos. 803 and 804, which remained well and probably possessed considerable natural immunity.

TABLE V.—*Results of Experiment IV on the infectiousness of blood, excreta, and secretions of infected pigs*—Continued

MATERIALS COLLECTED AND FED ON SEPTEMBER 21, 22, 24, AND 26, 1917 (SECOND, THIRD, FIFTH, AND SEVENTH DAYS)

Pig No.	Weight.	Material injected.	Result.
	Pounds.		
745	60	10 c. c. of eye-swab dilution...	Contracted hog cholera from contact with pig 746.
746	45	.....do.....	Sickened October 19 and died October 29. Cholera lesions.
[a] 747	65	10 c. c. of nose-swab dilution...	Remained well.
[a] 748	50	.....do.....	Do.
[a] 749	70	5 c. c. urine.....	Do.
[a] 750	55	.....do.....	Do.
[a] 751	60	2.5 gm. of feces in salt solution..	Do.
[a] 752	45	.....do.....	Do.

MATERIALS COLLECTED AND SCATTERED IN PENS ON SEPTEMBER 21, 22, 24, AND 26, 1917 (SECOND, THIRD, FIFTH, AND SEVENTH DAYS)

[a] 753	60	20 c. c. of eye-swab dilution...	Remained well.
[a] 754	45	.....do.....	Do.
755	65	20 c. c. of nose-swab dilution...	Sickened October 12 and died October 27. Cholera lesions.
756	50	.....do.....	Remained well.
[a] 757	70	200 c. c. of urine.....	Do.
[a] 758	55	.....do.....	Do.
[a] 759	60	30 gm. of feces in salt solution..	Do.
[a] 760	50	.....do.....	Do.

[a] These pigs were subsequently exposed to hog cholera by virus injections to test their immunity and all developed cholera except pig No. 758, which remained well and probably possessed considerable natural immunity.

In the four experiments which have just been described the virus was found to be present in the circulating blood of the cholera-infected pig on the first, second, third, fifth, seventh, and ninth days after injection.

The experiments indicate that the urine may be infectious as early as the first day after injection. In one experiment the urine was found to be infectious from the first to the ninth days, while in two experiments it was not infectious on the third day but was infectious on the fifth and seventh days. From these results it appears that, while the virus may be present in the urine earlier than the fourth day, it is quite regularly present in the urine of cholera-infected pigs by the fourth or fifth days.

In one experiment the virus was present in the feces on the second day, while in another experiment it was absent on the second day. In three experiments the virus was present in the feces on the third day, and it would thus appear that virus is thrown off quite regularly in the feces by the second or third day.

In two experiments the virus was absent from the eye and nose secretions on the second day, while in three experiments it was present in these secretions on the third day, and it is worthy of note that on those days there was no abnormal discharge from either the eyes or nose. It

would thus appear that the virus is present quite regularly in the eye and nose secretions by the third day.

The foregoing results are summarized in Table VI.

TABLE VI.—*Summary of results obtained in Experiments I to IV from injection tests of blood, excreta, and secretions of cholera-infected pigs*[a]

EXPERIMENT I

Days after injection.	Blood.	Urine.	Feces.	Eye secretions.	Nose secretions.
1	+	+	−	−	−
2	+	+	+	−	−
3	+	+	+	+	+
5	+	+	+	+	+
9	+	+	+	+	+

EXPERIMENT II

3	Not tested	−	+	+	+
5	do	+	+	+	+
7	do	+	+	+	+

EXPERIMENT III

7	+	+	+	+	+

EXPERIMENT IV

2	Not tested	−	−	−	−
3	do	−	+	+	+
5	do	+	+	+	+
7	do	+	+	+	+

[a] + indicates that the material was virulent: the injected pigs sickened or died. − Indicates that the material was not virulent: the injected pigs remained well, and contracted cholera upon subsequent exposure.

In contrast with the foregoing results, which were obtained by injecting the various materials, the results obtained from feeding the same materials and from scattering the same in pens with susceptible pigs were strikingly different. When fed and when scattered in pens, the freshly collected secretions and excreta obtained on the second, third, fifth, and seventh days proved to be noninfectious, with the possible exception of two pigs. One pig which was fed with eye secretion developed cholera 23 days after the date of the last feeding, and one pig exposed to nose secretion scattered in the pen developed hog cholera 16 days after the material was last scattered in the pen. It thus appears that although the virus is undoubtedly thrown off in the secretions and excreta of the sick animal at an early stage of the disease and the disease may be surely and readily

conveyed by injection, susceptible pigs do not readily contract the disease when fed with the infectious secretions and excreta or when exposed to these materials scattered in pens. These experiments suggest that perhaps the virus in the eye and nose secretions may be more readily conveyed by feeding and scattering than the virus in the urine and feces.

Secretions and excreta collected on the fifth and seventh days and held at room temperature (60° to 80° F.) for 24 hours proved to be infectious when injected. In the case of secretions and excreta which were collected on the seventh day and held at room temperature (60° to 75° F.) for 48 hours before injection, the urine and feces proved to be infectious, but the eye and nose secretions were no longer so. It should be noted that the eye and nose secretions were preserved on swabs and had dried before the last tests of virulence were made.

Of the four cholera-infected pigs which furnished the secretions and excreta for these experiments, two showed the first visible symptoms of sickness on the fourth day after injection, one on the sixth day, and one on the seventh day. As the experiments show that the virus is present quite regularly in the eye and nose secretions and in the feces by the third day, and may be present in the blood and urine as early as the first day, it becomes at once apparent that a cholera-infected pig may be a source of danger before the animal shows any visible symptoms of disease. A subsequent experiment (No. V) proves this danger to be a real one and that infected pigs may transmit the disease by contact during the period of incubation and before the appearance of visible symptoms. In this connection the possibility suggests itself that mild, unrecognized cases of hog cholera may occur and that such cases may be a factor in the spread of hog cholera.

CONTAGIOUSNESS OF HOG CHOLERA AT DIFFERENT STAGES OF THE DISEASE

The object of the following experiments was to determine whether, by mere contact, infected pigs are capable of transmitting hog cholera at all stages of the disease or whether there are certain periods, early or late, when the disease is not contagious. As will be seen, an endeavor was made to reduce, as far as possible, the likelihood of infection through contaminated pen litter.

EXPERIMENT V.—The experiment was carried out in the following manner: Three pigs, No. 1101, 1102, and 1103, were injected subcutaneously with blood from a sick pig on November 1 and were at once placed in a clean, disinfected pen, together with two uninoculated, susceptible pigs. The injected pigs and the susceptible, exposed pigs were allowed to remain together for 48 hours, at the end of which time the injected pigs and the exposed pigs were transferred to separate, clean, disinfected pens. Two more susceptible pigs were then placed with the injected pigs in their clean pen for 48 hours. The injected and

the exposed pigs were again transferred to separate, clean, disinfected pens. This was repeated at 48-hour intervals up to and including the tenth day.

The records of the three pigs which furnished the exposure are given in Table VII.

TABLE VII.—*Records of the three pigs which served as the source of hog-cholera infection*

Date.	Pig 1101.		Pig 1102.		Pig 1103.	
	Temperature.	Symptoms.	Temperature.	Symptoms.	Temperature.	Symptoms.
1916.	°F.		°F.		°F.	
Nov. 1	.....	Normal. Injected this day.	.....	Normal. Injected this day.	.....	Normal. Injected this day.
Nov. 2	103.8	Normal.....	104.0	Normal.....	103.7	Normal.
Nov. 3[a]	103.3	.....do.....	103.6	.....do.....	103.6	Do.
Nov. 4	104.7	.....do.....	104.2	.....do.....	104.4	Do.
Nov. 5[a]	.....	.....do.....	.....	.....do.....	.....	Do.
Nov. 6	104.4	Off feed.....	104.2	Off feed.....	104.4	Off feed.
Nov. 7[a]	103.6	.....do.....	104.2	.....do.....	103.6	Do.
Nov. 8	106.0	.....do.....	105.2	.....do.....	106.0	Do.
Nov. 9[a]	104.8	.....do.....	104.0	.....do.....	104.5	Do.
Nov. 10	103.8	Off feed; diarrhea.	105.4	.....do.....	105.4	Do.
Nov. 11[a]	104.4	.....do.....	104.4	.....do.....	105.4	Off feed; conjunctivitis, weakness, and diarrhea.

[a] The pigs were transferred to clean, disinfected pens on these dates and 2 susceptible pigs placed with them for 48 hours.

The subsequent history of the pigs which furnished the exposure was as follows: Pig 1101 died on November 14 and exhibited extensive hemorrhagic lesions of hog cholera. Pig 1102 developed conjunctivitis and had a fever temperature up to November 17; this pig recovered and was first reported as normal on November 24. Pig 1103 died on November 15, and showed hemorrhagic lesions with ulceration of cecum and colon.

The results of the experiment are shown in Table VIII.

Only 2 of the 12 exposed pigs escaped infection, and those were the two which were exposed to the infected pigs during the first 48 hours after injection. All of the other exposed pigs developed acute hog cholera and either died or were killed when in a moribund condition. The injected pigs which furnished the exposure did not show visible symptoms of disease until the fifth day.

TABLE VIII.—*Results of experiment V on the contagiousness of hog cholera (1916)*

[All pigs were exposed for 48-hour periods by association with cholera-sick pigs 1101, 1102, and 1103]

Pig No.	Weight.	Date exposed to sick pigs.	Date of transfer to disinfected pen.	Result.
	Pounds.			
1104	65	Nov. 1	Nov. 3	Remained well.
1105	65	Nov. 1	Nov. 3	Do.
1114	40	Nov. 3	Nov. 5	Died November 19; hemorrhagic lesions.
1115	20	Nov. 3	Nov. 5	Killed in moribund condition, November 27; hemorrhagic lesions.
1124	85	Nov. 5	Nov. 7	Died November 29; hemorrhagic lesions.
1125	70	Nov. 5	Nov. 7	Killed December 1; in advanced stage of disease; extensive hemorrhagic lesions; one ulcer in cecum.
1126	65	Nov. 7	Nov. 9	Died November 19; extensive hemorrhagic lesions.
1127	65	Nov. 7	Nov. 9	Killed in moribund condition November 20; extensive hemorrhagic lesions and ulceration of cecum and colon.
1134	70	Nov. 9	Nov. 11	Died November 22; hemorrhagic lesions.
1135	70	Nov. 9	Nov. 11	Killed in moribund condition November 27; hemorrhagic lesions with ulceration of cecum.
1144	65	Nov. 11	Nov. 13	Died November 30; extensive hemorrhagic lesions.
1145	70	Nov. 11	Nov. 13	Died December 1; extensive hemorrhagic lesions.

This experiment serves to corroborate Experiments I to IV, and shows very clearly that cholera-infected pigs may transmit the disease by contact prior to the appearance of visible symptoms. This is undoubtedly one of the reasons why the disease spreads so rapidly throughout a susceptible herd, once the infection has been established.

Experiment I indicated that the blood and urine of an inoculated pig were infectious 24 hours after inoculation and that the blood, urine, and feces were all infectious after 48 hours; yet in Experiment V the disease was not transferred by contact exposure during that period. It is an interesting and perhaps significant fact that the time at which contagiousness develops as shown by Experiment V coincides with the appearance of the infection in the eye and nose secretions. The number of experiments here recorded are only sufficient to permit the suggestion that perhaps the eye and nose secretions play a very important rôle in the dissemination of hog cholera.

Experiments VI, VII, VIII, and IX were carried out with a view to determining whether hog cholera may be transmitted by contact in the later or more advanced stages of the disease, as well as in the early stages.

EXPERIMENT VI.—This experiment was designed to afford a comparison between contact infection alone and combined pen infection and contact infection.

Four pigs, No. 1097x, 1098x, 1099, and 1100, were injected, each with 5 c. c. of virus blood on November 1 and were placed in the same pen. All of these pigs showed first visible symptoms on the fifth day after inoculation and developed the usual cholera symptoms. It was the intention to remove two of these sick pigs to a clean, disinfected pen at the end of 14 days, when the pigs would be in the late stages of the disease, and to expose two susceptible pigs with them; and two susceptible pigs were to have been exposed with the two pigs remaining in the original, infected pen. Pig 1100, however, died on the tenth day, exhibiting extensive hemorrhagic lesions at autopsy, so the experiment had to be modified as follows:

On November 11, ten days after inoculation and seven days after the appearance of first visible symptoms, pig 1099 was transferred to a pen which had been cleaned and disinfected and the disinfectant subsequently removed by washing. On the same date two susceptible pigs, No. 1138, and 1139, were placed in the disinfected pen with the sick pig, No. 1099. At the time of transfer, pig 1099 showed a temperature of 105.6° F. and was recorded as off feed and showing weakness, conjunctivitis, and diarrhea; this pig died four days later, on November 15, and the autopsy revealed estensive hemorrhagic lesions and ulceration of the cecum and colon. The two susceptible pigs, No. 1138 and 1139, promptly contracted hog cholera from contact with the sick pig, showing first visible symptoms on November 16, five days after exposure, and were found dead on November 21; both showed extensive hemorrhagic lesions at autopsy.

On November 11, two susceptible pigs, No. 1142 and 1143, were placed with the two remaining sick pigs, No. 1097x and 1098x, which had been left in the original, infected pen. At this time pig 1097x showed a temperature of 106.2° F. and was recorded as off feed and as showing conjunctivitis, weakness, and diarrhea; pig 1098x showed a temperature of 106.4° and was recorded as off feed and showing conjunctivitis and weakness. Pigs 1097x and 1098x both died on November 14, and both showed extensive hemorrhagic lesions at autopsy. The two susceptible pigs, No. 1142 and 1143, promptly contracted hog cholera, showing first visible symptoms on November 16, five days after exposure; they were found dead on November 21, and both showed extensive hemorrhagic lesions at autopsy.

It will be noticed that there was no difference in the results in the exposure in the clean, disinfected pen and the exposure in the original, contaminated pen; in other words, the contact of the susceptible pigs with the sick pigs was the essential factor in the conveyance of the disease, and the additional pen infection in the one case had no apparent effect on the development of the disease in the exposed pigs.

In this experiment the disease was transmitted by contact as late as the tenth day after infection, or the seventh day after the appearance of the first visible symptoms.

EXPERIMENT VII.—Pig 932 was injected with .5 c. c. of virus blood on October 25, showed first visible sickness on October 30, and developed the usual cholera symptoms. This pig was transferred to a clean, disinfected pen on November 11, 17 days after inoculation and 12 days after the first appearance of visible symptoms, and two susceptible pigs, No. 1140 and 1141, were placed in the same pen. At the time of transfer, pig 932 was off feed and showed a fever temperature, conjunctivitis, weakness, and diarrhea.

The two exposed pigs, No. 1140 and 1141, contracted cholera from contact with the sick pig and showed first visible symptoms on November 20, 9 days after exposure. Pig 1140 was killed when in a moribund condition, on November 25, showing extensive hemorrhagic lesions at autopsy. Pig 1141 died November 25 and exhibited extensive hemorrhagic lesions. Hog 932, which furnished the exposure, was found dead on November 16 and showed characteristic hemorrhagic lesions of cholera.

In this experiment the disease was transmitted by contact as late as the seventeenth day after inoculation, or the twelfth day after the appearance of first visible symptoms.

EXPERIMENT VIII.—Pig 794 was injected with 5 c. c. of virus blood on June 30. The animal was first visibly sick on July 7 and developed characteristic cholera symptoms. On July 21, 21 days after inoculation and 14 days after the appearance of visible symptoms, this pig was first scrubbed with soap and water, next with compound cresol solution, again with soap and water, and was transferred to a clean, disinfected pen. A susceptible pig, No. 811, was placed in the same pen. At the time of transfer, pig 794 showed a temperature of 103.8° and was recorded as off feed and as showing conjunctivitis, diarrhea, and red skin.

The exposed pig, No. 811, contracted hog cholera from contact with the sick pig, showing the first visible symptoms on July 25, four days after exposure; this pig died on July 30, and the autopsy revealed hemorrhagic lesions. Pig 794, which furnished the exposure, died on August 4 and showed hemorrhagic lesions and ulceration of cecum and colon.

In this experiment the disease was transmitted by contact as late as the twenty-first day after inoculation, or the fourteenth day after the appearance of first visible symptoms.

EXPERIMENT IX.—Pig 904 contracted hog cholera by association with sick pigs and developed characteristic cholera symptoms, including weakness, loss of appetite, conjunctivitis, and diarrhea. This pig was transferred to a clean, disinfected pen on October 28, 21 days after the appear-

ance of first visible symptoms, and two susceptible pigs, No. 1093 and 1094, were placed in same pen. At the time of transfer pig 904 was recorded as being off-feed, in poor condition, and as showing diarrhea.

The two exposed pigs, No. 1093 and 1094, contracted cholera from contact with the sick pig and showed the first visible symptoms on November 3. Both of these pigs died on November 10. Pig 1094 showed hemorrhagic lesions at autopsy and No. 1093 showed hemorrhagic lesions with ulceration of cecum. Pig 904, which furnished the exposure, died on October 30, showing hemorrhagic lesions with extensive ulceration of the cecum and colon.

In this experiment the disease was transmitted by contact as late as the twenty-first day after the appearance of first visible symptoms.

In the four experiments which have just been described, susceptible pigs were exposed to sick pigs on the seventh, twelfth, fourteenth, and twenty-first days after the appearance of first visible symptoms of sickness. All of the exposed pigs contracted hog cholera as a result of the exposure.

The preceding experiments, No. V to IX, inclusive, show that hog cholera is contagious at all stages, even including the stage of incubation. They indicate also that an infected hog remains a source of danger at least until the time of complete recovery.

RECOVERED PIGS AS CARRIERS OF HOG CHOLERA

Suspicion has long rested on the recovered pig as a possible carrier of hog cholera, but there seems to be little, if any, experimental evidence on this point. This lack of experimental evidence is no doubt largely due to the difficulty of obtaining hogs which have had genuine attacks of cholera and have subsequently made a complete recovery.

In the course of the experiments which were carried out during the summer and fall of 1916, four pigs were secured which had suffered from acute, typical hog cholera, and which had made apparently good recoveries. The following experiments were carried out with these animals.

EXPERIMENT X.—Pig 893 was injected with virus on September 13, 1916, and within the usual time developed an acute case of cholera, but made an apparently good recovery. The clinical record of this pig is given in full in Table IX.

TABLE IX.—*Record of recovered pig 893*

Date.	Temperature.	Symptoms.
1916.	°F.	
September 13	101. 7	Normal.
September 14	102. 8	Do.
September 15	102. 8	Do.
September 16	105. 6	Slow.
September 17	Not taken.	Off-feed.
September 18	105. 0	Do.
September 19	104. 0	Do.
September 20	105. 4	Off-feed, weakness, conjunctivitis, and purple ears.
September 21	104. 6	Do.
September 22	104. 1	Do.
September 23	105. 0	Do.
September 24	Not taken.	Do.
September 25	102. 3	Do.
September 26	102. 5	Eating a little.
September 27	102. 3	Eating a little; improvement.
September 28	103. 0	Do.
September 29	102. 3	Do.
September 30	102. 3	Do
October 1	Not taken.	Eating more; improvement.
October 2	101. 9	Do.
October 3	101. 0	Normal.
October 4	102. 0	Do.
October 5	101. 6	Do.

On October 6, when this hog had entirely recovered, it was thoroughly scrubbed, first with soap and water, and next with compound cresol solution, and again with soap and water. The pig was then transferred to a clean, disinfected pen, and a susceptible pig, No. 1029, was placed in the same pen. The two pigs were in close association from October 6 to 26, a period of 20 days, during which time the susceptible pig remained perfectly well. Pig 1029 was injected with virus on October 27 to test its susceptibility and died on November 4, eight days later, with well-marked hemorrhagic lesions.

In order to determine whether pig 893 harbored the virus of hog cholera in its blood, this animal was bled from the tail on October 6 and 5 c. c. of the defibrinated blood was injected into pig 1031. Pig 1031 was kept under careful observation from October 6 to 27, a period of three weeks, and remained perfectly normal. Pig 1031 was injected with 5 c. c. of virus on October 27 to test its susceptibility. It contracted cholera and was killed for virus eight days later, the autopsy revealing well-marked hemorrhagic lesions and beginning ulceration of the cecum.

EXPERIMENT XI.—Pig 951 was injected with virus on August 29, was off-feed on the fifth day, and developed a marked temperature reaction and conjunctivitis, but made a good recovery. The clinical record of this pig following the virus injection is given in Table X.

TABLE X.—*Record of recovered pig 951*

Date.	Temperature.	Symptoms.
1916.	°F.	
August 30	103.6	Normal.
August 31	104.4	Do.
September 1	104.5	Do.
September 2	104.4	Do.
September 3	.....	Off-feed.
September 4	106.1	Do.
September 5	106.4	Off-feed; conjunctivitis.
September 6	105.6	Do.
September 7	106.2	Do.
September 8	101.7	Do.
September 9	103.8	Do.
September 10	.....	Do.
September 11	103.4	Eating a little.
September 12	103.0	Do.
September 13	102.8	Do.
September 14	103.5	Do.
September 15	103.2	Do.
September 16	102.1	Eating better.
September 17	.....	Do.
September 18	103.5	Do.
September 19	102.0	Normal.
September 20	102.6	Do.
September 21	102.0	Do.

On September 21 pig 951 was thoroughly washed, first with soap and water, then with compound cresol solution, and again with soap and water, and was then transferred to a clean, disinfected pen. A susceptible pig, No. 1011, was then placed in the pen with pig 951. The two pigs were kept in the pen together from September 21 to October 19, a period of four weeks, and during this time the pen check or control remained perfectly normal. On October 19 the control pig, No. 1011, was removed and injected with virus blood to test its susceptibility; the animal sickened as a result of the injection, was off its feed for a week, and showed a marked temperature reaction, but recovered.

In order to determine whether the virus was present in the blood of pig 951, this animal was bled from the tail on October 6 and 5 c. c. of the defibrinated blood were used for the injection of pig 1030. This animal was kept under observation from October 6 to October 27, a period of three weeks, and remained perfectly well. On October 27 it was injected with 5 c. c. of virus blood to test its susceptibility and was killed for virus eight days later, the autopsy showing characteristic hemorrhagic lesions and ulceration of cecum.

EXPERIMENT XII.—Pig 1046 was injected with 5 c. c. of urine from a cholera-sick pig, No. 1032x, on October 13, and developed a typical, acute case of hog cholera, but made a good recovery. This pig was one of those used in the experiment to determine the infectiousness of the blood, excreta, and secretions of cholera-infected pigs. Its record is

included in Table II. The clinical record of this pig is given in full in Table XI.

TABLE XI.—*Record of recovered pig 1046*

Date.	Temperature.	Symptoms.
1916.	°F.	
October 14	102. 4	Normal.
October 15	.....	Do.
October 16	102. 6	Do.
October 17	102. 6	Do.
October 18	102. 6	Do.
October 19	103. 0	Do.
October 20	102. 6	Do.
October 21	101. 6	Do.
October 22	.....	Do.
October 23	104. 6	Do.
October 24	106. 1	Slow.
October 25	105. 6	Off-feed.
October 26	104. 8	Ate some feed.
October 27	104. 7	Off-feed.
October 28	104. 0	Do.
October 29	.....	Off-feed; red ears.
October 30	104. 5	Do.
October 31	105. 3	Off-feed; red ears, and diarrhea.
November 1	105. 0	Do.
November 2	103. 8	Do.
November 3	105. 0	Do.
November 4	104. 4	Do.
November 5	.....	Do.
November 6	102. 8	Ate some feed.
November 7	102. 2	Do.
November 8	105. 0	Do.
November 9	102. 8	Do.
November 10	103. 8	Do.
November 11	104. 0	Do.
November 12	.....	Ate feed; general improvement.
November 13	103. 6	Do.
November 14	103. 2	Do.
November 15	104. 6	Do.
November 16	103. 2	Do.
November 17	103. 0	Normal.
November 18	103. 0	Do.
November 19	.....	Do.
November 20	102. 6	Do.
November 21	102. 0	Do.
November 22	103. 0	Do.
November 23	.....	Do.
November 24	.....	Do.
November 25	102. 6	Do.

On November 24, two susceptible pigs, Nos. 1180 and 1181, were placed in the pen with pig 1046. In this instance pig 1046 was not scrubbed; nor was the pen disinfected. The three pigs were in close association from November 24 to December 15, a period of 21 days, during which time they remained well. All three pigs were injected with virus on December 15. Pig 1046 remained well. Pigs 1080 and 1081 became sick on December 20, showing loss of appetite, and some elevation of temperature, but recovered and were reported normal on December 29.

This experiment is not quite as satisfactory as the three others, as the two exposed pigs did not die as a result of the virus injection which was given them in order to test their susceptibility. They undoubtedly possessed some degree of natural immunity, but the fact that they both sickened after the virus injection serves to establish their susceptibility.

EXPERIMENT XIII.—Pig 1070 was injected with 5 c. c. of a normal salt dilution of nasal secretion from pig 1032x on October 16, 1916, and developed a typical, acute case of hog cholera, but made a good recovery. This pig was one of those used in the experiment to determine the infectiousness of the blood, excreta, and secretions of cholera hogs, the record of which is included in Table II.

The clinical record is given in full in Table XII.

TABLE XII.—*Record of recovered pig 1070.*

Date.	Temperature.	Symptoms.
1916.	°F.	
October 17	103.6	Normal.
October 18	103.7	Do.
October 19	103.1	Do.
October 20	103.8	Do.
October 21	106.5	Off feed.
October 22	.....	Do.
October 23	107.0	Do.
October 24	105.5	Do.
October 25	106.7	Do.
October 26	106.5	Off feed; purple ears.
October 27	106.1	Do.
October 28	105.9	Off feed; conjunctivitis; weakness.
October 29	.....	Do.
October 30	104.8	Do.
October 31	103.0	Do.
November 1	103.8	Do.
November 2	102.7	Do.
November 3	103.6	Ate some feed.
November 4	103.9	Do.
November 5	.....	Do.
November 6	105.0	Off feed; diarrhea.
November 7	100.6	Do.
November 8	102.9	Do.
November 9	103.8	Do.
November 10	102.9	Do.
November 11	101.0	Ate some feed; diarrhea.
November 12	101.0	Do.
November 13	102.1	Do.
November 14	101.4	Do.
November 15	101.6	Do.
November 16	102.0	Do.
November 17	.....	Do.
November 18	101.0	Do.
November 19	101.0	Do.
November 20	102.3	Do.
November 21	102.8	Do.
November 22	102.8	Do.
November 23	102.8	Do.
November 24	104.4	Do.
November 25	103.0	Ate feed.

TABLE XII—*Record of recovered pig 1070*—Continued.

Date.	Temperature.	Symptoms.
1916.	°F.	
November 26	103.0	Ate feed.
November 27	103.4	Normal.
November 28	102.8	Do.
November 29	102.8	Do.
November 30	.....	Do.
December 1	102.0	Do.
December 2	101.9	Do.
December 3	.....	Do.
December 4	.....	Do.
December 5	103.1	Do.

From the above record it will be seen that hog 1070 had a typical and well-marked case of hog cholera, the temperature going as high as 107°. On December 4, eight days after the animal was recorded as normal, two suceptible pigs, Nos. 1196 and 1197, were placed in the pen with hog 1070. In this experiment the pen was not disinfected; nor was the recovered pig washed and disinfected as in the first two experiments. The three pigs were kept together from December 5 to 27, a period of 22 days, during which time they remained well.

All three pigs were injected with virus on December 27 to test their immunity. Hog 1070 remained well. Pigs 1196 and 1197 became sick on January 1, 1917, developed the usual symptoms of hog cholera, and were killed for virus on January 9, each showing well-marked hemorrhagic lesions of hog cholera at autopsy.

In the four experiments which have just been described, recovered pigs which had suffered from typical attacks of hog cholera were tested by exposure with susceptible pigs and also by the withdrawal of blood and the inoculation of susceptible pigs to determine whether they harbored the virus within their bodies and could act as carriers of the disease. In all four experiments the results were entirely negative.

These experiments do not, of course, show that recovered pigs may not at times be carriers of hog cholera; yet, on the contrary, they do prove that all recovered pigs are not carriers. When these results are considered with those of experiments I to VI, we may conclude, that although hogs which have been infected with cholera are dangerous so long as they show any symptoms of cholera, they may lose the power to convey the disease to others, once they have made a good recovery.

PIGEONS AS CARRIERS OF HOG CHOLERA

The belief that birds play an important part in the dissemination of hog cholera is based largely upon practical observations, such as an outbreak of cholera on a farm frequented by pigeons that are known to

fly to and from an infected farm. This belief is founded also upon the knowledge that the virus of cholera exists in the carcasses of dead hogs and on premises occupied by herds that are infected with the disease. It is reasonable to assume that any agency likely to carry bits of tissue from carcasses of hogs that have died of cholera, as for example, buzzards, or any agency likely to carry particles of dirt from an infected hog lot, as, for example pigeons, may serve to disseminate hog cholera. However, although there is ample ground for suspecting that certain birds do at times carry the disease from one farm to another, absolute and convincing evidence upon this point is lacking. The following experiments were carried out with the object of securing definite experimental data relative to the likelihood of the conveyance of hog cholera by pigeons.

Two pens, 5 feet square, were placed facing each other, 10 feet apart, and the space between was inclosed with wire netting. Small hinged doors were cut in the sides of the pens, so that the pigs could be fed from the outside. The upper portion of the front of each pen was left open. The pens bore the numbers 19 and 22 (fig. 1).

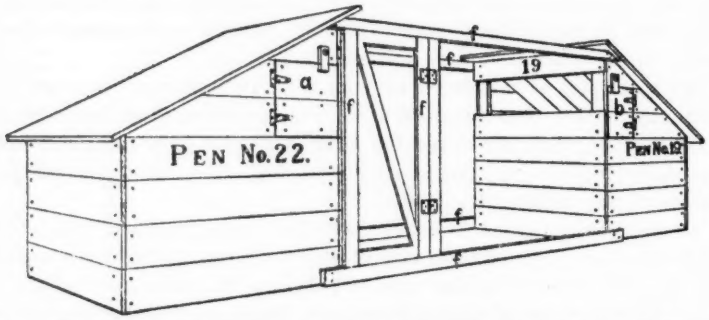

FIG. 1.—Diagram showing the arrangement of pens for pigeon experiments: *a*, *b*, Doors for feeding and watering pigs; *f*, *f*, framework for holding wire netting.

EXPERIMENT XIV.—Two pigs, No. 2283 and 2284, were injected with hog-cholera virus and placed in pen 19 on September 18. Two uninoculated, susceptible pigs, No. 2285 and 2286, were placed in pen 22 on the same date. Six pigeons were placed within the wire inclosure, the birds having free access to both pens through the open fronts. No food was placed in the space between the pens and the birds were forced to go into the pens with the pigs to secure their food.

The two injected pigs in pen 19 developed characteristic cholera symptoms and died on September 26, showing extensive hemorrhagic lesions and intestinal ulceration at autopsy. The pigeons were frequently in the pen with the sick pigs and even sat on the bodies of the sick pigs when these were in a moribund condition. They were also frequently in the pen with the exposed pigs.

Two more pigs, No. 2317 and 2318, were injected with virus and placed in pen 19 on September 30, to replace the two pigs which had died there and to keep up the infection in this pen. Both of these pigs developed cholera, No. 2317 dying on October 8 and No. 2318 on October 18. Both animals showed extensive hemorrahgic lesions at autopsy.

The two uninoculated pigs, No. 2285 and 2286, in clean pen 22 remained perfectly well from September 18 to October 18, a period of 30 days, in spite of the fact that during this time they were daily subjected to possible infection from virus carried on the feet of the pigeons, which divided their time between the pens, flying freely from side to side. In order to test the susceptibility of pigs 2285 and 2286, and at the same time prove that the virus of hog cholera was present in the litter of pen 19, these pigs, without being treated in any way, were transferred from clean pen 22 to infected pen 19 on October 18. Both pigs picked up the infection from the pen and developed typical hog cholera, pig 2286 dying on November 6 and pig 2285 on November 17. At autopsy both pigs revealed extensive hemorrhagic lesions and intestinal ulceration. It was thus shown that the two pigs which were exposed to the pigeons for 30 days were susceptible pigs and that the virus of the hog cholera was present in the litter of pen 19, but was not carried over by the pigeons.

EXPERIMENT XV.—Two uninoculated, susceptible pigs, No. 2457 and 2458, were placed in clean pen 22, on October 20, for exposure to the pigeons. During the period from October 20 to November 17, pen 19 was occupied by infected pigs (see Experiment XIV). Upon the death of the last of these, on November 17, two more uninoculated, susceptible pigs, No. 2766 and 2767, were placed in infected pen 19. These two pigs, like their immediate predecessors, picked up the infection from the pen, and developed typical hog cholera. Both died on November 27, showing extensive hemorrhagic lesions and intestinal ulceration.

On November 29 the pigeons, which had alighted and fed in both pens 19 and 22 continually since October 20, were shut off from pen 22. They remained excluded until December 15, in order to give time for any infection that had been carried by them to develop in the two susceptible pigs, No. 2457 and 2458. These two pigs continued perfectly well throughout the entire period, although they had been exposed to possible infection by the pigeons for 40 days, from October 20 to November 29.

On December 15, pigs 2457 and 2458, having failed to contract disease from exposure to the pigeons, were transferred from pen 22 to pen 19, and each injected with 5 c. c. of hog-cholera virus. This was done in order to test the susceptibility of these pigs and to furnish fresh infec tion to pen 19. Both pigs developed hog cholera following the virus injection and both died on January 7, 1916, exhibiting extensive hemorrhagic lesions and intestinal ulceration at autopsy.

EXPERIMENT XVI.—Two susceptible pigs, No. 2939 and 2940, were placed in pen 22 on December 16, and the pigeons were allowed free access to this pen, as well as to pen 19, which then contained infected pigs 2457 and 2458 (see Experiment XV). The last-named pigs died on January 7, and were removed from pen 19, which remained unoccupied until January 17, when susceptible pigs No. 3480 and 3481 were each injected with 5 c. c. of blood from a sick pig and placed in pen 19. Both of these pigs contracted cholera from the inoculation; one died on January 31, and the other on February 1, and both exhibited extensive lesions of hog cholera at autopsy.

Pigs 2939 and 2940 were kept in pen 22 from December 16 to February 5. For 37 days of this period infected pigs were kept in pen 19, while during the entire period of 51 days the pigeons had free access to both pens. On February 5, of pigs 2939 and 2940, which had remained well, were each injected with 5 c. c. of virus blood to test their susceptibility. Both developed hog cholera as a result of the injections.

Pig 2939 died on February 14, showing extensive hemorrhagic lesions at autopsy, and hog 2940 died on February 27, showing extensive hemorrhagic lesions and intestinal ulceration.

The results of the three experiments with pigeons as carriers of hog cholera are epitomized in Table XIII.

TABLE XIII.—*Results of tests to determine whether pigeons are disseminators of hog cholera*

Pig No.	Date placed in pen 22.	Purpose.	Length of time exposed to pigeons.	Remarks.
	1915.			
2283	.....	.....	.....	
2284	.....	.....	.....	
2317	.....	.....	.....	
2318	.....	.....	.....	
2285	Sept. 18	Exposure to pigeons	30 days	Remained well while in pen 22.
2286	Sept. 18	.....do	30 days	Do.
2766	.....	.....	.....	
2767	.....	.....	.....	
2457	Oct. 20	Exposure to pigeons	40 days	Remained well while in pen 22.
2458	Oct. 20	.....do	40 days	Do.
2939	Dec. 16	.....do	37 days	Remained well while in pen 22. Injected with 5 c. c. of virus on Feb. 5, 1916.
2940	Dec. 16	.....do	37 days	Do.
3480	.....	.....	.....	
3481	.....	.....	.....	

TABLE XIII.—*Results of tests to determine whether pigeons are disseminators of hog cholera*—Continued

Pig No.	Date placed in pen 19.	Purpose.	Died.	Post-mortem lesions.
	1915.		1915.	
2283	Sept. 18	Injected with 5 c. c. of virus to furnish pen infection.	Sept. 26	Extensive hemorrhages and intestinal ulceration.
2284	Sept. 18	.....do.....	Sept. 26	Do.
2317	Sept. 30	.....do.....	Oct. 8	Extensive hemorrhages.
2318	Sept. 30	.....do.....	Oct. 18	Do.
2285	Oct. 18	To test susceptibility and furnish pen infection.	Nov. 17	Extensive hemorrhages and intestinal ulceration.
2286	Oct. 18	.....do.....	Nov. 6	Do.
2766	Nov. 17	To continue pen infection.....	Nov. 27	Do.
2767	Nov. 17	.....do.....	Nov. 27	Do.
			1916.	
2457	Dec. 15[a]	Injected with 5 c. c. of virus to test susceptibility and furnish pen infection.	Jan. 7	Do.
2458	Dec. 15[a]	.....do.....	Jan. 7	Do.
2939	.....	.....	Feb. 14	Extensive hemorrhages.
2940	.....	.....	Feb. 27	Extensive hemorrhages and intestinal ulceration.
	1916.			
3480	Jan. 17	Injected with 5 c. c. of virus to furnish pen infection.	Feb. 1	Extensive hemorrhages.
3481	Jan. 17	.....do.....	Jan. 31	Do.

[a] Pigeons were shut out of pen 22 from November 29 to December 15 in order to give time for any infection carried by them to develop in the exposed pigs.

In these experiments three lots of pigs, each lot consisting of two pigs, were exposed to possible infection from virus carried by pigeons, at a distance of 10 feet from a heavily infected pen. In the experiments the periods of exposure were 30, 37, and 40 days, respectively, with negative results in each case. In these tests the exposure of susceptible pigs to possible infection from virus carried by pigeons was severe and long continued. The pen which contained the sick pigs was not cleaned during the course of the experiment and became very foul from the excreta of the sick pigs; the pigeons were constantly passing from the heavily infected pen to the pen containing the well pigs; and the distance between the two pens was only 10 feet. Every opportunity was afforded, therefore, for prolonged periods of time, for the pigeons to carry the infection a very short distance.

It goes without saying that these experiments do not prove that it is impossible for pigeons to convey hog cholera. They do indicate, however, that the disease is probably not often carried in that way.

EXPERIMENTS TO DETERMINE WHETHER RATS MAY HARBOR THE VIRUS OF HOG CHOLERA

In considering the various agencies which might be concerned in the spread of hog cholera, the possibility suggested itself that rats which had fed on the carcasses of cholera pigs might play a part in the spread of the disease, and the following preliminary experiments were carried out to test this point:

EXPERIMENT XVII.—Two gray rats which were caught on the Station premises were fed daily for five days with meat from the carcasses of

cholera-infected pigs. The two rats were then killed; the bodies were chopped up in their entirety and, mixed with bran mash, were fed to two susceptible pigs, No. 1118 and 1119.

The two pigs were kept under observation from November 4 to 24, a period of 20 days, and remained well. They were exposed to hog cholera by virus injection on November 24, showed the first symptoms of sickness on November 29, developed the usual cholera symptoms, and were killed for virus on December 1. Both pigs showed slight but characteristic lesions at autopsy.

EXPERIMENT XVIII.—Two gray rats which were caught on the Station premises were fed daily from October 31 to November 20, a period of 21 days, with the meat of cholera-infected pigs. The two rats were killed on November 21. They were then chopped up, mixed with bran mash, and fed to two susceptible pigs, No. 1174 and 1175. The pigs were under observation from November 21 to December 8, a period of 17 days, and remained well. The pigs were exposed to hog cholera by virus injection on December 8, showed the first visible symptoms on December 11, developed the usual cholera symptoms, and were killed for virus on December 15. Each pig showed hemorrhagic lesions of hog cholera at autopsy.

In these experiments rats which had been fed on the meat of cholera pigs for 5 days and 21 days, respectively, were killed and the entire carcasses fed to susceptible pigs without producing sickness.

GENERAL SUMMARY AND CONCLUSIONS

Although the data obtained from these experiments are not sufficient to warrant sweeping conclusions, the results are nevertheless quite suggestive, and they serve to bring out some interesting points which may be summarized as follows:

(1) The eye and nose secretions, the blood, the urine, and the feces of cholera-infected pigs were tested on the first, second, third, fifth, seventh, and ninth days after infection. When injected, the eye and nose secretions and fecal suspensions, were found to be infectious on the third day; the urine was quite regularly infectious by the fourth or fifth day and the blood was infectious as early as the first day. When fed and when scattered in pens, the freshly collected secretions and excreta were noninfectious as a rule. Secretions and excreta which were held at room temperature (60° to 85° F.) for 24 hours remained infectious when injected. When the secretions and excreta were held at the same temperature for 48 hours the urine and feces remained infectious, but the eye and nose secretions were no longer so. It might appear, therefore, that outside the animal body the virus in the eye and nose secretions succumbs more quickly than the virus

in the urine and feces, but such a conclusion is not justified by these experiments, as the virus from the eye and nose was allowed to dry on swabs. This point requires further study with the virus from the different sources held under identical conditions. Finally, it should be noted that the eye and nose secretions may be infectious before there is any visible discharge from the eyes or nose.

(2) Susceptible pigs were exposed by association with cholera-infected pigs for 48-hour periods on the first, third, fifth, seventh, ninth, and eleventh days after infection. With the exception of those exposed on the first and second days—that is, during the first 48-hour interval—all of the exposed pigs contracted hog cholera. Other pigs which were exposed to cholera-infected pigs at 17 and 21 days contracted hog cholera. Cholera-infected pigs therefore may transmit the disease by contact at practically all stages of the disease, even in the period of incubation, before the appearance of visible symptoms and before the animal can be recognized as sick.

(3) Susceptible pigs were exposed by being placed in pens with pigs which had suffered from typical attacks of hog cholera but had recovered. Other susceptible pigs were inoculated with blood drawn from the recovered pigs. Four recovered pigs were tested in this way to determine whether they harbored the virus of cholera within their bodies and might act as carriers of the disease. None of the pigs exposed to the recovered pigs, either by association or by blood injection, developed hog cholera. The exposed pigs were later proved to be susceptible by virus injection.

(4) Susceptible pigs were exposed for long periods of time to pigeons, which passed daily from a heavily infected pen only 10 feet away and which contained sick and dying pigs, to a pen containing susceptible pigs. The exposure in these experiments was severe, as the pigeons were afforded every opportunity to carry the infection over a very short distance. Notwithstanding this, none of the exposed pigs developed cholera. All of the exposed pigs were later proved to be susceptible either by virus injection, by association directly with sick pigs, or by exposure in an infected pen. These experiments extended through the fall and well into the winter. While the assumption would hardly be warranted that pigeons never convey hog cholera, it does not seem likely that they are often concerned in the spread of this disease.

(5) Rats were fed on the meat of cholera hogs for periods of 5 and 21 days. The rats were then killed, their entire bodies chopped up, mixed with bran mash, and the mixture was fed to susceptible pigs. None of the pigs thus fed contracted cholera. The pigs were proved to be susceptible by subsequent virus injection.

EFFECT OF TEMPERATURE AND OTHER METEOROLOGICAL FACTORS ON THE GROWTH OF SORGHUMS

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HISTORICAL REVIEW

The botanical group *Andropogon sorghum* includes an extensive and widely varying list of cultivated crop plants which are primarily subtropical in their climatic requirements, although many varieties are now being grown well north in the temperate regions. The effect of temperature and other meteorological factors on the sorghums has not been discussed very extensively in agricultural literature.

Sachs (*5, p. 365*)[1] determined the minimum, optimum, and maximum temperatures for wheat, barley, pumpkin, beans, and corn as follows:

Plant.	Minimum.	Optimum.	Maximum.
	°F.	°F.	°F.
Wheat	41	83.7	108.5
Barley	41	83.7	99.9
Pumpkin	56.7	92.7	115.2
Beans	49.1	92.7	115.2
Corn	49.1	92.7	115.2

The above figures, however, are for seedlings (germinating seeds), and while the results are indicative, it is probably true that the more fully developed plants would continue to grow under wider extremes.

The work of other investigators, Mayer, Heinrich, etc., indicate that the optimum temperatures for the growth of the nasturtium (*Tropaeolum majus*), the water violet (*Hottonia palustris*), and white mustard (*Sinapis alba*) also lie between 88° and 95° F. Bose (*3, p. 445*) found the optimum temperature for the Crinum lily, the peduncle of the crocus, and and the hypocotyl of the balsam to be 95° F.

It would seem from these tests that the optimum temperature for a considerable number of plants is between 83° and 95° F. From the

[1] Reference is made by number (italic) to "Literature cited," p. 147.

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writers' knowledge of sorghum they have reason to believe that its temperature requirements resemble those of beans (Fabaceae) and corn (*Zea mays*) more closely than they do those of wheat (*Triticum* spp.) and barley (*Hordeum* spp.) The optimum temperature for the growth of sorghum is quite likely about 92° or 93°. Above this optimum, growth is retarded by further increases in temperature until the maximum is reached, when growth ceases entirely, and continued exposure to the maximum temperature will cause death. Just how the high temperatures (those above the optimum) effect this retardation of the growth is not well understood. Vines (*8, p. 283-284*) states that many physiologists believe the fatal effect of high temperatures is due to the coagulation of the coagulable proteids of the cell, but this has not been proved. He goes on to say:

> It is doubtless upon the living protoplasm of the cell that the temperature acts; the effect first manifests itself by a diminution of the metabolic activity of the protoplasm, and ultimately effects its disorganization.

Kreusler found that assimilation in species of Ricinus and Rubus begins to decrease at 86° and at 113° F. is stopped almost entirely.

Balls (*2*), who worked on the "sore shin" fungus of cotton, attributed this decrease of assimilative power and growth in the presence of high temperatures to the accumulation of katabolic products in the cell and not to any inability of the protoplasm to function at temperatures of 98° to 100° F., which he determined as the practical stopping point of growth in the "sore-shin" fungus.

Ewart's (*4, p. 385–387*) work seems to confirm Balls's theory. He found that plants of corn, beans, pumpkins, etc., subjected for three days to temperatures of 98° to 100° F., if well supplied with oxygen and moisture, showed no inhibitory after effect, but if the supply of air were limited a retardation of assimilation was induced which persisted for sometime after the temperature had been reduced to a point most favorable for the plant's growth. Thus, it would appear that it may be a failure properly to dispose of the products of katabolism which interferes with continued assimilation and growth at superoptimal temperatures.

Carefully controlled tests would have to be made, of course, in order to determine whether sorghum behaves as these other plants have done under similar temperatures; but observations in the field at Bard, Cal., indicate that there is a slowing up of growth in nearly all field crops during the hottest part of the summer, when air temperatures in the daytime are often consistently above 100° F.

The manner in which low temperatures act upon the plant to decrease its rate of growth has been studied less than the effect of high temperatures. The minimum temperature for growth has been determined for a number of plants, and several investigators have studied in detail

the effect of freezing plants; very few of these, however, have considered the effect of suboptimal temperatures on the retardation of growth. It has been observed that the processes of metabolism become less pronounced at low temperatures. This slowing up of the growth is due perhaps to a decrease in enzymic action, as well as to the failure of the protoplasm to function properly at such temperatures.

Although light is necessary for the normal development of chlorophyllous plants, but little is known regarding the effect of different intensities of light on their growth. Sachs (*6*) found that the rate of growth in the seedlings of maize increases during the night and decreases during the day, the period of greatest growth being early in the morning just as it is becoming light. Smith (7), in testing Blackman's theory of limiting factors, made an extensive series of growth measurements on the new culms or growing shoots of bamboo. In all but one instance these measurements showed a more rapid growth at night than in the daytime. Smith concluded there were two factors which controlled the growth: (1) temperature of the culm, and (2) supply of water to the culm. The second factor, being intimately connected with the amount of water drawn off by the transpiration of adult culms on the same rhizome, was influenced in its turn by two factors: First, the humidity of the atmosphere, and second, the intensity of the light. At night the greater humidity of the atmosphere and the lessened transpiration due to the absence of light both contributed to the certainty of an adequate supply of water for the growing shoot.

The measurements of Sachs and of Smith were made on growth produced from reserve food stored in the plant itself, and the results can not be applied to the behavior of general farm crops like sorghum, for it is known that in green plants the continued absence of light results in etiolation and eventually in a cessation of growth. A certain amount of light is ordinarily required in the formation and functioning of chlorophyll. Without sunlight the green plant is powerless to form new organic compounds, and its growth in darkness comes about only through the transformation of organic compounds already at its disposal.

The observations of Linsser, Marie-Davy, and Angot, as noted by Abbe (*1, p. 211–290*), show that there exists a decided difference in the quantity of heat necessary for the development of the same species of plants in different latitudes, and Marie-Davy asserts that the determining influence is the quantity of light which the plants receive. Abbe (*1, p. 79*) also points to some work of Hellriegel with barley, in which it was found that plants in the open air made a 50 per cent larger yield than those grown inside a greenhouse in the direct sunshine, and fully three times as much as plants grown in diffuse light under glass.

OUTLINE OF EXPERIMENTS AND DESCRIPTION OF WEATHER CONDITIONS

In the preceding discussion literature has been cited only for the purpose of an introduction to the presentation of the data obtained in the following experiments. No attempt has been made to make the review of the literature complete or even extensive. It is believed that the limited data obtained in the field tests hereafter described will be of value not only in establishing the climatic limitations of the sorghums but also in indicating the principles which underlie the results of numerous "Date of planting" experiments with this crop.

It has been noticed that the sorghums behave very peculiarly in localities which have continuously low temperatures. In 1915 an attempt was made to obtain data on this effect of low temperatures by growing certain selected varieties of sorghum under widely varying climatic conditions. Plantings were made at Puyallup, Wash.; Chico, Berkeley, Bard, and Pasadena, Cal.; and Chillicothe, Tex. It was thought that these points represented the extremes of humidity and heat, as well as the more intermediate conditions. At Puyallup the temperatures and the percentage of sunshine are low through the summer, and the nights are cool. At Berkeley there is high humidity with moderate temperatures, while at Chico and Bard the temperatures are high, the humidity low, and the sunshine abundant. At Pasadena and Chillicothe somewhat intermediate climatic conditions prevail.

Very complete notes were made regarding the growth of these sorghums at Berkeley, but the plots were not irrigated; and as there was practically no rain from May until September, the lack of soil moisture may have exerted as much influence on their growth as did the weather factors. It has seemed best, therefore, to substitute for the Berkeley results of 1915 those obtained at Chula Vista in 1916. Summer conditions at Chico and Bard, Cal., are so similar and the results so nearly alike that only the results at Bard are given. In like manner Chillicothe was chosen to represent intermediate climatic conditions.

Table I gives in considerable detail the chief features of the weather at Chillicothe, Bard, and Puyallup in 1915 and Chula Vista in 1916, showing the maximum, minimum, mean, and normal temperatures, the mean relative humidity, the inches of rainfall, and the percentage of actual to possible sunshine for each month.

For Chillicothe only the rainfall and mean monthly temperature records were obtained directly at that point. The relative humidity and percentage of sunshine are those recorded by the United States Weather Bureau at Abilene, Tex., and the remainder of the data was taken from the Weather Bureau records for Quanah, Tex., 13 miles west of Chillicothe. It is probable that the relative humidity at Abilene, 130 miles south of Chillicothe, is a trifle too low and the percentage of sunshine may

be 3 or 4 per cent too high, but the figures represent very closely conditions at Chillicothe.

The data for Bard were taken from the Weather Bureau records for Yuma, Ariz., which is only 7 miles distant and is practically the same elevation as Bard.

The data as given for Chula Vista, Cal., are taken from the Weather Bureau records at San Diego, Cal., which is 12 miles from Chula Vista and similarly located in respect to its proximity to the ocean.

There were no complete weather records for Puyallup, Wash., at any point nearer than Tacoma, Wash., 8 miles distant, but since these two places are very similarly located, it is believed that the data from Tacoma represent conditions at Puyallup closely enough for the purposes of this study.

TABLE I.—*Weather conditions during 1915 and 1916*

CHILLICOTHE, TEX., 1915 [a]

Month.	Temperature (° F.).						Mean relative humidity.	Rainfall.	Percentage of actual to possible sunshine.
	Maximum.		Minimum.		Mean for month.	Normal for month.			
	Mean.	Absolute.	Mean.	Absolute.					
							Per cent.	*Inches.*	
January	51.7	68	32.0	18	38	40.5	65	0.34	70
February	60.3	74	40.8	31	46	40.2	56	1.88	70
March	53.5	86	39.2	29	41	52.1	67	1.22	50
April	74.1	89	56.8	42	63	63.5	69	5.13	60
May	79.1	93	57.4	45	68	70.5	64	2.15	75
June	89.2	103	61.7	54	78	79.6	62	6.71	80
July	95.7	109	70.1	58	81	83.3	56	4.07	75
August	91.0	107	65.6	51	76	82.5	63	3.73	75
September	89.6	106	66.6	51	75	76.6	.....	3.83	70
October	80.1	90	54.2	41	63	63.4	69	5.07	85
November	72.6	95	42.8	24	55	51.7	52	.15	85
December	62.7	82	32.3	19	46	40.2	58.5	.53	65
Yearly	75.0	109	51.6	18	60.8	62.0	61.9	34.81	71.7

BARD, CAL., 1915 [b]

January	64.9	74	42.6	34	53.7	54.7	52.5	2.56	72
February	68.8	73	44.7	37	56.8	59.2	57.0	.72	81
March	79.2	91	50.0	36	64.6	64.7	44.5	T.	90
April	83.7	97	54.4	47	69.0	70.1	46.0	.08	89
May	88.9	104	56.3	39	72.6	76.8	43.0	T.	93
June	104.3	112	66.5	59	85.4	84.7	40.0	0.00	98
July	104.8	110	75.2	63	90.0	90.9	45.0	.34	93
August	107.7	116	74.4	67	91.0	91.9	45.0	.41	94
September	97.8	109	65.0	54	81.4	83.9	49.5	.10	95
October	94.9	104	55.8	49	75.4	73.4	41.0	T.	98
November	76.1	91	47.7	38	61.9	61.9	37.5	T.	89
December	67.8	79	41.1	28	54.4	55.7	45.5	.12	78
Yearly	86.6	116	56.1	28	71.4	72.3	45.5	4.33	89.1

[a] Only the rainfall and mean monthly temperatures were taken at Chillicothe, the relative humidity and sunshine are as reported by the Weather Bureau Station at Abilene, Tex.; the other records are as reported at Quanah, Tex.

[b] Data from the Weather Bureau Station at Yuma, Ariz.

TABLE I.—*Weather conditions during 1915 and 1916*—Continued

PUYALLUP, WASH., 1915[a]

Month.	Temperature (° F.).						Mean relative humidity.	Rainfall	Percentage of actual to possible sunshine.
	Maximum.		Minimum.		Mean for month.	Normal for month.			
	Mean.	Absolute.	Mean.	Absolute.					
							Per cent.	*Inches.*	
January	44.7	55	33.2	18	37.5	38.1	85	5.87	21
February	49.8	59	37.0	25	42.6	40.4	84	3.41	19
March	57.9	74	41.6	29	48.7	44.2	76	2.34	41
April	60.9	74	43.7	31	51.4	48.9	71	3.93	53
May	63.6	79	47.3	36	55.0	54.4	71	3.42	37
June	68.3	88	50.9	40	59.4	59.4	72	.43	48
July	73.3	90	55.2	46	64.8	63.4	71	2.28	44
August	77.3	89	56.0	44	65.2	63.0	66	.00	58
September	67.0	76	50.8	35	57.6	57.6	74	1.11	45
October	60.5	68	46.4	33	52.4	50.6	79	3.43	27
November	48.0	55	38.1	26	42.2	44.1	86	9.46	10
December	47.2	60	36.7	20	40.6	40.3	82	9.26	20
Yearly	59.9	90	44.7	18	51.4	50.4	76.4	44.9	35.3

CHULA VISTA, CAL., 1916[b]

January	58.2	65	46.7	36	52.4	54.0	82	7.56	48
February	63.5	78	49.2	38	56.4	54.6	81	.66	66
March	65.8	81	52.5	43	59.2	56.2	78	.98	69
April	66.7	79	53.8	48	60.2	58.2	78	.01	76
May	65.8	72	55.9	50	60.8	60.8	75	.01	73
June	66.2	74	56.7	52	61.4	63.8	83	T.	62
July	69.1	74	60.8	58	65.0	66.9	84	.02	59
August	72.0	84	61.9	58	67.0	68.7	84	.01	71
September	69.1	80	59.6	56	64.4	66.9	87	.25	62
October	65.1	78	53.5	46	59.3	63.0	83	.87	69
November	65.0	74	48.0	39	56.5	59.0	74	.05	81
December	60.2	76	44.6	38	52.4	55.7	75	1.14	62
Yearly	65.4	84	53.6	36	59.6	60.7	80.3	11.56	66.5

[a] Data from the Weather Bureau Station at Tacoma, Wash.
[b] Data from the Weather Bureau Station at San Diego, Cal.

The most striking features brought out in Table I are the high percentage of sunshine and the consistently high temperatures, especially during the months of June, July, and August, at Bard, Cal., and in contrast with this the very low figures for these two climatic features at Puyallup, Wash. The mean maximum temperature for June, July, and August at Bard is considerably over 100° F. for each month. This, according to the figures obtained by Sachs for corn, would indicate an excess of heat units during a part of the day at least. At Puyallup, Wash., even the maximum temperatures do not reach the presumed optimum for sorghums, and the actual mean temperature for the growing season is about 30° below this optimum (Table II). This lack of heat units no doubt is largely responsible for the indifferent growth which the sorghums made at Puyallup.

In order that the main features of difference can be more easily comprehended, a summary of weather conditions for the growing season alone is brought together in Table II.

TABLE II.—*Synopsis of weather conditions during the growing seasons* [a] *at Chillicothe, Tex., Bard and Chula Vista, Cal., and Puyallup, Wash.*

Station and year.	Temperature (°F).						Average of mean relative humidity.	Total rainfall.	Percentage of actual to possible sunshine.
	Maximum.		Minimum.		Average of monthly means.	Average of monthly normals.			
	Average of means.	Absolute.	Average of means.	Absolute.					
							Per cent.	*Inches.*	
Chillicothe, Tex. (1915)	88.9	109	64.3	45	75.6	78.5	61.3	20.50	75.0
Bard, Cal. (1915)	97.9	112	65.3	39	81.8	82.9	40.1	[b] 1.54	93.4
Chula Vista, Cal. (1916)	68.1	72	56.8	39	62.4	64.9	82.4	[b] 1.20	68.4
Puyallup, Wash. (1915)	69.9	90	52.0	35	60.4	59.6	70.7	7.24	46.4

[a] At Chillicothe, Bard, and Puyallup the months of May, June, July, August, and September were considered as the growing season. At Chula Vista the data for July, August, September, October, and November were used to make up the averages in the table because the sorghums were planted there in the latter part of June.

[b] Irrigation water supplied to the crop as needed.

In 1915 the rainfall at Chillicothe during the growing season was much above and the temperatures somewhat below the normal. Conditions, except for a short period during July, were rather favorable for rapid growth.

The seasons at Bard do not vary much from year to year. The summer season is characterized by heat so extreme that it seems to have a retarding effect on the growth of the ordinary field crops. These high temperatures are accompanied by low atmospheric humidity. The rainfall is negligible, but an abundance of soil moisture is supplied through irrigation.

The seasons differ but little at Chula Vista from year to year, but 1916 happened to be about 2 degrees cooler than normal and this seemed detrimental to the sorghums.

The rainfall at Puyallup, which averaged about 1½ inches per month, seems rather inadequate, but in the four months preceding the period under consideration there were 15.55 inches of rainfall, which no doubt left the soil full of moisture. This fact, taken in consideration with the low temperatures and small amount of sunshine, makes it appear probable that there was no serious deficiency in soil moisture during the summer.

EXPERIMENTAL RESULTS

COMPARISON OF THE GROWTH OF SORGHUM VARIETIES UNDER DIFFERENT WEATHER CONDITIONS

A general comparison of the growth of Sumac, Red Amber, and Honey sorgos, Blackhull kafir, Dwarf milo, and feterita is given in Table III.

TABLE III.—*Comparison of the growth of sorghum varieties at Chillicothe, Tex., Bard and Chula Vista, Cal., and Puyallup, Wash.*

Variety and location.	Date planted.	Date emerged.	Date 90 per cent ripe.	Growing season.	Final height.	Diameter of stem.	Remarks.
				Days.	*In.*	*In.*	
Sumac sorgo:							
Chillicothe	May 21	May 25	Sept. 13	115	80	0.75	A normal vigorous growth.
Bard	Apr. 22	Apr. 27	Sept. 2	133	108	.75	Tall, vigorous growth.
Chula Vista	May 23	May 29	Oct. 31	161	68	.63	Fairly normal growth, not especially vigorous.
Puyallup	May 15	May 30	(a)	[a] 143	30	.....	October 5, growth low and spreading, leaves somewhat curled; not yet heading.
Red Amber sorgo:							
Chillicothe	May 21	May 25	Aug. 13	84	64	.63	Uniform growth.
Bard	Apr. 14	Apr. 20	Aug. 10	118	90	.69	Normal, vigorous growth.
Chula Vista	June 27	July 2	Oct. 31	126	90	.56	A typical, fine-stemmed growth.
Puyallup	May 15	May 30	.....	143	40	.....	A few heads in bloom on October 5. Growth somewhat spreading. Leaves curled and red on the edges.
Honey sorgo:							
Chillicothe	May 21	May 25	Oct. 6	138	96	1.00	Late, rank growth.
Bard	Apr. 14	Apr. 20	Aug. 31	139	99	.75	A good, vigorous growth, some tendency to lodge.
Chula Vista	June 28	July 3	Nov. 12	137	92	.75	Medium height. growth normal.
Puyallup	May 15	June 1	.....	143	11	.....	A low, spreading inferior growth. No heads.
Blackhull kafir:							
Chillicothe	May 21	May 25	Sept. 10	112	62	1.00	Normal, vigorous growth.
Bard	Apr. 16	Apr. 21	Sept. 2	139	72	.81	Good, vigorous growth.
Chula Vista	June 28	July 3	Dec. 5	160	74	.94	Uniform growth and well-filled seed heads.
Puyallup	May 15	May 29	.....	143	33	.....	October 5, growth quite upright, but with no heads.
Dwarf milo:							
Chillicothe	May 21	May 25	Aug. 30	101	50	.75	Uniform, vigorous growth.
Bard	Apr. 22	Apr. 27	Aug. 30	130	58	.56	Typical milo of poor forage value, but good grain.
Chula Vista	June 29	July 4	Nov. 5	129	50	.50	Typical milo, but with rather numerous tillers.
Puyallup	May 15	May 29	.....	143	27	.....	October 5, beginning to head, but very undersized.
Feterita:							
Chillicothe	May 21	May 25	Aug. 13	84	58	.63	Uniform, vigorous growth.
Bard	Apr. 20	Apr. 25	Aug. 12	114	65	.50	Stems too slender for typical milo.
Chula Vista	June 29	July 4	Nov. 10	134	66	.69	Fair growth, but did not seem at home under these conditions.
Puyallup	May 15	May 29	.....	143	18	.....	October 5, growth spreading, leaves curled and red on edges, no heads.
Average:							
Chillicothe	.....	.....	.....	106	68	.79	
Bard	.....	.....	.....	129	82	.68	
Chula Vista	.....	.....	.....	141	73	.68	
Puyallup	.....	.....	.....	.....	27	.....	

[a] None of the varieties matured at Puyallup, so that the growing season for each variety represents only the period from the date of planting to October 5.

All of the varieties under discussion are thoroughly at home under the climatic conditions at Chillicothe. A long experience in growing sorghum at this point indicates that Chillicothe's climate is well suited to the requirements of the crop and the results there may be taken as a criterion of normality of growth (Pl. 11, 12). The data in the table show an average growing season for the varieties under consideration of 106 days at Chillicothe, as compared with 129 days at Bard, and 141 days at Chula Vista. We find, however, in Table V that a later date of plant-

ing at Bard, will shorten the growing season 21 days, thus making the normal growing season at Bard 108 days, which is about the same as at Chillicothe. This is assumed as the normal growing season for Bard, since the growth of sorghums planted at this date is more nearly normal than when planted earlier.

The longer growing season at Bard and Chula Vista seem to have resulted in an increase in height most noticeable at Bard, where the plants averaged 14 inches taller than at Chillicothe. Again, however, we find by consulting Table V that where the sorghums were planted later and the growing season was shortened the height was reduced an average of 8 inches. This would make the average height for Bard 74 inches, only 6 inches taller than at Chillicothe. At Chula Vista the average height was 73 inches, which is but little over normal. The average height of 27 inches at Puyallup emphasizes the very inferior growth which the sorghums made under the conditions existing there.

In diameter of stem the climatic effect is the reverse of that where height is concerned. The stems were larger and stronger at Chillicothe. than at either Bard or Chula Vista. If we take into consideration the effect of the time of planting at Bard, however, the difference in diameter at Chillicothe and Bard is very slight, only 0.02 inch.

On the whole Table V shows that a normal growth may be expected at both Chillicothe and Bard if the time of planting at the latter point is properly regulated. At Chula Vista the rather low temperatures lengthened the growing season very markedly and caused the plants to have somewhat slender stems. At Puyallup, where low day temperatures were combined with a very decided deficiency in the sunshine and with cool nights the sorghums did not behave normally, and all failed to mature.

At Puyallup measurements were taken every two weeks on the growth made by the sorghum varieties, and these measurements emphasized the backwardness of the growth. For Sumac sorgo the growth was for the first month, 4 inches; second month, 3 inches; third month, 10 inches; and fourth month, 13 inches. Blackhull kafir grew in the first month only 4 inches: second month, 4 inches; third month, 12 inches; and fourth month, 12 inches. Dwarf milo, which was the only variety that headed, made a growth of 5 inches the first month; 2 inches the second month; 12 inches the third month; and 9 inches the fourth month. This low rate of growth indicates a temperature too low to stimulate properly the growing functions of sorghums, or else the deficiency of sunshine had a very decided retarding effect on their growth. The percentage of possible sunshine was only 46 at Puyallup, while it was 68 at Chula Vista.

The total degrees of positive temperature[1] received by the sorghums at Puyallup was 1,615° F., at Chula Vista, 1,895°, at Bard, 4,236°, and at Chillicothe 3,028°. The difference between the total seasonal heat units at Chula Vista and Puyallup is rather small, and it is difficult to believe that this difference in heat units is alone responsible for the failure of the sorghums to reach the heading stage at Puyallup, while they matured perfectly at Chula Vista.

Evidently there was an excess of heat at Bard above what the plants could utilize, since they ripened at Chula Vista with 2,341° F. and at Chillicothe with 1,208° less positive heat units than were available at Bard during the period covered by their growth. The old theory of botanists that a given total of heat units will produce the same phase of vegetation regardless of latitude, longitude, or local climatic conditions is thus disproved, but the results do substantiate Linsser's law of growth as described by Abbe (*1, p. 214*).

This law can be stated as follows: In two different localities the sums of positive daily temperatures for the same phase of vegetation is proportional to the annual sum total of all positive temperatures for the respective localities—that is, the heat required in any locality to produce a given phase of development in vegetation bears a constant ratio to the total positive heat units available in that place. This ratio has been styled the "physiological constant." If 50° F. is considered as the minimum temperature for growth in the sorghums, the yearly total of positive heat units at Chillicothe in 1915 was 5,618° F.; at Bard, 1915, 7,989°; and at Chula Vista, 1916, 3,600°. The positive heat units required to bring the sorghums to maturity at Chillicothe were 3,028° F., at Bard, 4,236°, and at Chula Vista 1,895°. It appears, therefore, that the physiological constant of sorghum for the period from planting to maturity is about 0.53. The conformance of the sorghums in these three cases to Linsser's law is rather remarkable, the exact ratio in each case being as follows:

Chillicothe	3,028:5,618, or 0. 539
Bard	4,236:7,989, or .530
Chula Vista	1,895:3,600, or .526

Although Linsser's law seems to furnish a rule for the behavior of sorghums in respect to temperature, it does not take into account the effect of sunlight and other factors, which are also important.

The data for a more exact comparison of the growth attained by certain varieties of sorghum at Bard and Chula Vista have been assem-

[1] These totals were calculated according to the second method of Angot described by Abbe (*1, p. 79*), except that 50° F. was taken as the zero point of growth instead of 43° F. Sachs (*2*) determined the minimum temperature for corn as 49.1° F., and as sorghum is notably more sensitive to low temperatures than corn, 50° F. was chosen arbitrarily as the minimum temperature for growth, and only those temperatures above 50° F. were used in compiling the totals. For Chula Vista, Bard, and Chillicothe the totals are based on the average season required by the sorghums for maturity. At Puyallup it includes the period from the date when the sorghums were planted until the first killing frost in the fall.

TABLE IV.—*Comparison of the growth of sorghums at Bard and at Chula Vista, Cal.*

Variety.	Serial No.	Date planted.		Growing season.			Stems.						Leaves.									Panicle.					
							Height.			Diameter.			Number.			Length.			Width.			Length.			Diameter.		
		Chula Vista.	Bard.	Chula Vista.	Bard.	Excess, Chula Vista.	Chula Vista.	Bard.	Excess, Bard.	Chula Vista.	Bard.	Excess, Bard.	Chula Vista.	Bard.	Excess, Bard.	Chula Vista.	Bard.	Excess, Bard.	Chula Vista.	Bard.	Excess, Bard.	Chula Vista.	Bard.	Excess, Bard.	Chula Vista.	Bard.	Excess, Bard.
		1916.	1916.	*Days.*	*Days.*	*Days.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*				*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
White African sorgo	1546	June 27	June 14	136	120	16	111	112	1	0.75	1.19	0.44	12	17	5	31	25	−6	3.25	3.5	0.25	7	7.5	0.5	2.75	5	2.25
Blackhull kafir	17569	June 28	...do....	160	120	40	74	68	−6	.94	.94	.00	13	16	3	31	25	−6	4.25	4	−.25	9.5	10.0	.5	3.25	2.75	−.5
Dwarf hegari	34911	May 24	...do....	121	121	0	42	60	18	.38	.88	.5	7	19	12	20	34	14	2	3.5	1.5	6.5	7.5	1.0	1.75	3.25	1.5
Brown kaoliang	38199	June 30	June 15	135	108	27	72	78	6	.5	.5	.00	10	10	0	22	26	4	2.75	2.25	−.5	7	7.5	.5	2.5	3.5	1
Average						20.75			4.75			.24			5			1.5			.25			.63			1.06
		1915.																									
Red Amber sorgo	17548	June 27	Apr. 14	126	118	8	90	90	0	.56	.69	.13	8	10	2	22	30	8	2.5	3.25	.75	12	12	.00	9.5	3.5	−6
Sumac sorgo	17554	May 23	...do....	161	164	−3	64	108	44	.75	.94	.19	12	18	6	29	33	4	3.25	3	−.25	6.5	6.5	.00	2.25	2	−.25
Dwarf milo	18684	June 29	Apr. 19	132	106	26	40	59	19	.5	.56	.06	6	8	2	23	26	3	2.25	2.75	.5	7	6.5	−.5	3.5	2.25	−1.25
Planter sorgo	18930	June 28	Apr. 14	156	123	33	88	92	4	.63	.75	.12	11	12	1	30	32	2	3.5	3.5	.00	8.25	9	.75	3.25	4.5	1.25
Feterita	19517	June 29	Apr. 20	136	118	18	70	70	0	.69	.56	−.13	9	9	0	27	24	−3	3.25	2.75	−.5	6.5	8	1.5	3.25	4	.75
Red kafir	19742	May 23	Apr. 16	160	182	−22	74	78	4	.63	.94	.31	10	17	7	27	32	5	3.25	3	−.25	12	12	.00	2.25	2.5	.25
Collier sorgo	19770	...do....	Apr. 20	168	176	−8	95	126	31	.75	1.06	.31	11	17	6	32	37	5	3.5	3	−.5	12.5	9.5	−3	5.5	.....	.....
Florida sorgo	20813	June 28	Apr. 14	167	154	13	100	112	12	.81	1.06	.25	14	16	2	27	34	7	3	3.25	.25	7.5	10	2.5	2.75	2.25	−.5
Freed sorgo	29166	...do....	...do....	133	117	16	73	66	−7	.38	.38	.00	6	7	1	25	24	−1	3	2.5	−.5	12	11	−1	7.5	7	−.5
Orange sorgo	32889	May 23	May 17	161	142	19	76	96	20	.69	1	.31	12	16	4	34	36	2	3.75	3.5	−.25	10.75	10	−.75	3.5	2.5	1
Gooseneck sorgo	32893	June 28	Apr. 15	137	153	−16	88	88	0	.63	.63	.00	10	12	2	26	27	1	3.25	3.25	.00	7	10	3	3	4.5	1.5
Standard milo	35048	June 29	May 17	139	108	31	63	80	17	.5	.56	.06	7	7	0	30	25	−5	3.25	2.25	−1	7	7	.00	3.5	2.5	−1
Average						9.58			12			.13			2.75			2.33			−.15			.21			−.61

bled in Table IV. The comparison of weather conditions at these two points, both of which are in southern California, is available in Tables I and II.

It will be noted in Table IV that most of the data from Bard are for the year 1915, while those for Chula Vista are for 1916. The weather conditions at Chula Vista and Bard are so uniform from year to year that the comparison has practically the same value as if all the plantings had been made in 1915 at both places. The greatest factor of uncertainty in the tabulated data is the effect of the date of planting. At Bard in 1915 most of the numbers were planted about the middle of April, while in 1916 the plantings were not made until the middle of June. The effect which this early planting had on the sorghums is brought out more fully in Table V. It can be said here, however, that the later planted sorghums were more nearly normal, especially in the seed parts.

Table IV gives a comparison not only of the growing season and height, but also of the number, length, and width of the leaves, and the length and diameter of the panicles. For the varieties which were planted at both places in June the magnitude of all characters was greater at Bard than at Chula Vista and the growing season was shorter. This difference of 21 days in the growing season is perhaps a fair measure of the effect of the low temperatures and reduced actinic value of the sun's rays at Chula Vista. High fogs obscure the sun quite often for hours in the morning and evening, and the temperature is seldom above 70° F. for any considerable part of the day. At Bard, on the other hand, desert conditions prevail, the sky is usually cloudless and the sunlight is intense, while the temperatures reach a maximum of over 100° F. day after day. Considering only the three varieties White African sorgo, Blackhull kafir, and Brown kaoliang which were planted at Bard on June 14, 1916, and at Chula Vista only two weeks later, the sum total of the positive temperatures received from planting date to maturity was at Bard 4,301° F. and at Chula Vista 1,923° F. It is evident, therefore, that although the growing season averaged 28 days shorter at Bard there was available for the plants' use a much larger number of heat units than at Chula Vista. These conditions resulted in taller, slightly larger stems, and a greater number of leaves which were both longer and wider, except in the early planted sorghums at Bard which had slightly narrower, though longer leaves than at Chula Vista. The panicle was larger at Bard, especially in the sorghums which were planted at both places in June.

The most remarkable variation which took place, however, is in the number of leaves, a character that has heretofore been considered relatively stable. All the plantings were made with seed from bagged heads, so the variation can not be attributed to cross-pollination. Dwarf hegari, which exhibits an extreme variation of 12 leaves, is notoriously

variable, but Blackhull kafir 17569, Sumac sorgo 17554, and most of the other varieties listed are standard strains which are known to be stable. Blackhull kafir showed a difference of 3 in the number of leaves under the differing conditions, and Sumac sorgo had 6 more leaves at Bard than at Chula Vista. Evidently unfavorable conditions of growth cause a reduction in the number of leaves and this character is, therefore, of uncertain value as a basis of classification or botanical description.

Table IV is even more interesting for the study of individual varieties than it is in a study of the average variation. Thus, Dwarf hegari, Dwarf and Standard milos, and Sumac, Collier, Florida, and Orange sorgos show a striking difference in height under different weather conditions, while the other varieties vary much less in height, but fully as much or more than above-named sorts in the size of the leaf and panicle.

EFFECT OF THE DATE OF PLANTING ON THE GROWTH OF SORGHUMS

The effect of different dates of planting on the growth of sorghum plants is set forth in Table V. Other things being equal, this effect apparently is correlated with the presence of high temperatures at different periods of the life cycle. In 1915, when the plantings were made in April, the early stages of growth took place in a period of moderate temperatures, and the flowering and fruiting functions were carried on in a period of very high temperatures. In 1916 the plantings were made about the middle of June. Growth began during a period of high temperatures and maturity took place when conditions were more moderate.

A study of Table I in connection with Table V shows the relation that the period of high summer temperatures bears to the growing periods of each planting. The conditions in 1916 were practically the same as in 1915. A comparison of the mean temperatures with the normals shows how uniform the seasons are at Bard.

An examination of Table V shows that deferring the planting date 55.5 days shortened the growing season for the 12 varieties under test an average of 21 days. In spite of the shorter growing season in 1916 the total of positive heat units available during the period of growth in the two years was practically the same, 4,628° F. in 1915 and 4,318° in 1916. The early date of planting and longer growing season produced taller plants and longer leaves, but in all other characters the excess in magnitude was with the later planting. On the whole, the plants from the later planting were more nearly normal in their growth and produced a better seed crop. It would appear, therefore, that more favorable conditions of growth are obtained if the date of planting is regulated so that the early stages of the plant's development coincide with a period of high temperatures and the later stages, when the plant is nearing maturity, come when moderate temperatures prevail.

TABLE V.—*Comparison of the growth of sorghums when planted on different dates at Bard, Cal.*

Variety.	Serial No.	Date planted.			Growing season.			Stems.						Leaves.									Panicle.					
								Height.			Diameter.			Number.			Length.			Width.			Length.			Diameter.		
		1915	1916	Difference in dates.	1915	1916	Excess, 1915.	1915	1916	Excess, 1915.	1915	1916	Excess, 1916.	1915	1916	Excess, 1916.	1915	1916	Excess, 1915.	1915	1916	Excess, 1916.	1915	1916	Excess, 1916.	1915	1916	Excess, 1916.
				Days.	*Days*	*Days*	*Days*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*				*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*
White African sorgo	1546	May 15	June 14	30	143	120	23	114	112	2	0.75	1.19	0.44	16	17	1	30	25	5	3	3.5	0.5	6.5	7.5	1.00	2.75	5	2.25
Shallu	2650	Apr. 22	June 15	54	142	119	23	110	102	8	.75	.75	.00	14	15	1	36	34	2	3.25	3.5	.25	12.0	12.0	0	7	7	.00
Blackhull kafir	17569	Apr. 16	June 14	59	139	120	19	72	68	4	.81	.94	.13	16	16	0	34	25	9	3.75	4	.25	10	10	0	2.5	2.75	.25
Red kafir	19751	Apr. 16	June 14	59	136	118	18	108	95	13	.75	.88	.13	16	13	− 3	36	29	7	4	3.5	− .5	9	9.75	.75	1.75	2	.25
Red kafir	19756	Apr. 16	June 14	59	139	114	25	108	95	13	.88	1.31	.43	16	15	− 1	34	28	6	3.5	4	.5	11	11	0	2.5	3.75	1.25
White kafir	19764	Apr. 16	June 14	59	145	119	26	122	107	15	.75	.88	.13	18	17	− 1	33	26	7	3.5	3.88	.38	10	9	− 1	3.5	4.75	1.25
White kafir	19765	Apr. 16	June 14	59	149	120	29	98	74	24	.81	1	.19	17	14	− 3	35	27	8	3.5	4	.5	12	12	0	2.25	5	2.75
Pink kafir	19906	Apr. 16	June 14	59	143	120	23	94	66	28	.88	.88	.00	18	15	− 3	35	28	7	3.5	3.88	.38	11.5	12	.5	1.5	2.25	.75
Blackhull kafir	22653	Apr. 16	June 14	59	167	119	48	78	67	11	1	.88	− .12	19	15	− 4	33	29	4	4	3.75	− .25	11.5	12.5	1	2.75	3	.25
Red milo	24963	Apr. 19	June 14	56	113	111	2	70	80	− 10	.56	.69	.13	9	13	4	27	25	2	3	3.25	.25	7.5	7	− .5	2.5	3.75	1.25
Dwarf hegari	34911	Apr. 17	June 14	58	117	121	− 4	53	60	− 7	.56	.88	.32	8	19	11	25	34	−9	2.5	3.5	1	8.5	7.5	− 1	2	3.25	1.25
Brown kaoliang	38199	Apr. 21	June 15	55	127	108	19	74	78	− 4	.69	.5	− .19	12	10	− 2	24	26	− 2	3	2.25	− .75	7	7.5	.5	3.5	3.5	0
Average				55.5			21			8.08			.13			0			3.83			.13		.10			.96

SUMMARY

(1) Sorghum is semitropical in its adaptations and does not thrive in regions of low temperatures.

(2) Sunshine is probably an important factor of growth; witness the difference of growth at Chula Vista, Cal., and Puyallup, Wash., where the mean temperatures and the total positive heat units available are but little different.

(3) The "physiological constant" for the ripening phase of sorghums according to Linsser's law of growth is about 0.53.

(4) Extremely high temperatures during the period of flowering and fruiting result in a decreased yield of seed.

(5) The date of planting should be so arranged that germination and early growth of the plants will take place during the period of high temperatures and the flowering and fruiting when more moderate temperatures prevail.

(6) Adverse weather conditions affect such supposedly stable characters as the number of leaves per plant, as well as the volume of growth.

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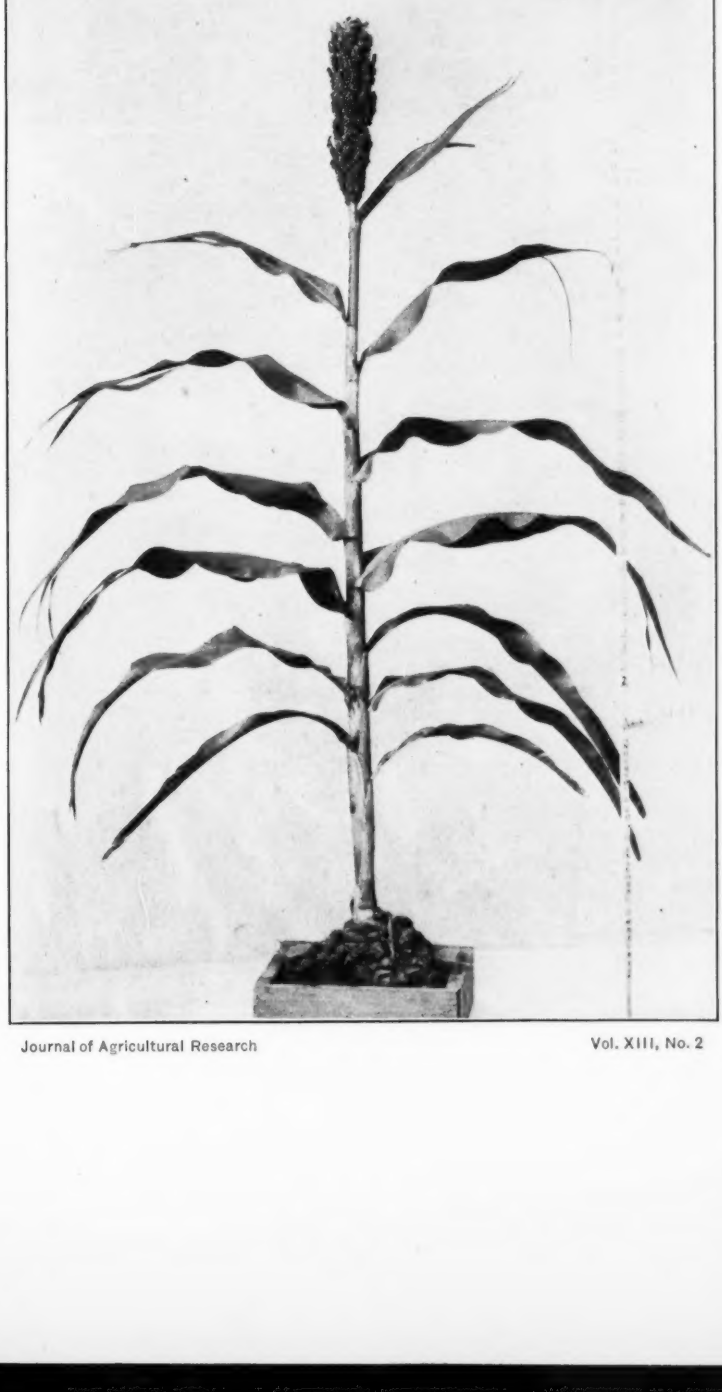
PLATE 11

A typical plant of Blackhull kafir grown at Chillicothe, Tex.



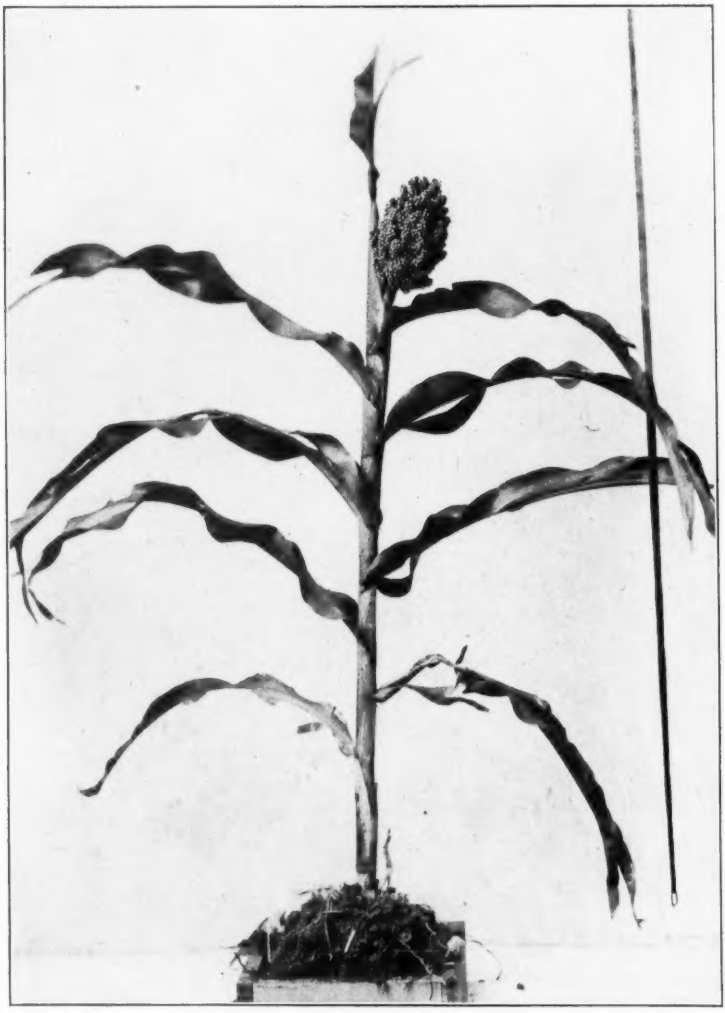


PLATE 12

A typical plant of Dwarf milo grown at Chillicothe, Tex.